



Georectification

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One of the basic precondition for successful creation of geographical database, data analysis and synthesis as well as map outputs is suitable unified reference system use.



Unique reference system – basic precondition for GIS project accomplishment

In practice we usually use 3 ways of location – reference systems:

1. input data - maps
2. internal – for processing
3. output data – maps

Internal reference system selection depends on:

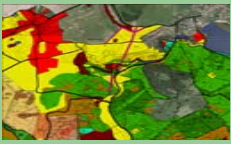
- extent of processed area
- project importance

Reference systems

- local
- national
- international



- 1. Projections**
- 2. Transformations**
- 3. Resampling**
- 4. Orthorectification**



1. Projection

Physical Earth surface – surface with specific morphological formations created by natural forces affection

Geoid – zero level equipotencial surface that has in every point orthographic projection to gravity direction

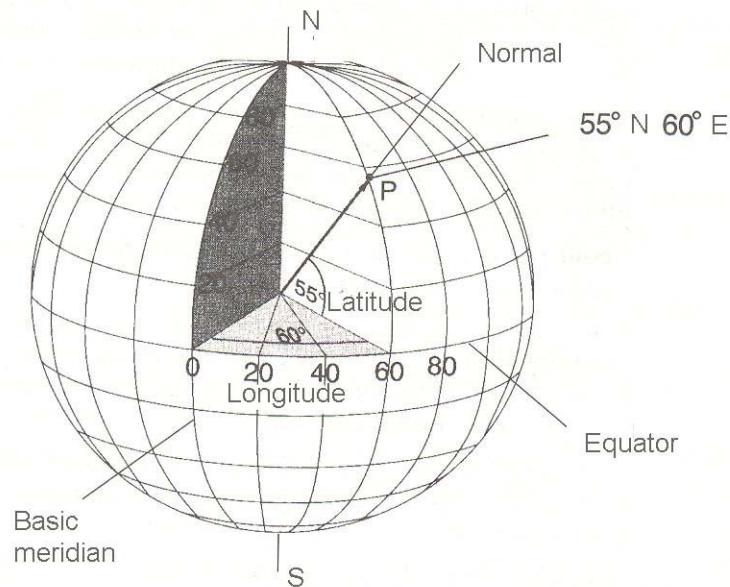
Reference ellipsoid – ellipsoid that is very near to geoid surface.

To make calculations easier the ellipsoid surface is substituted by spherical surface many times.



Point location on earthborn body

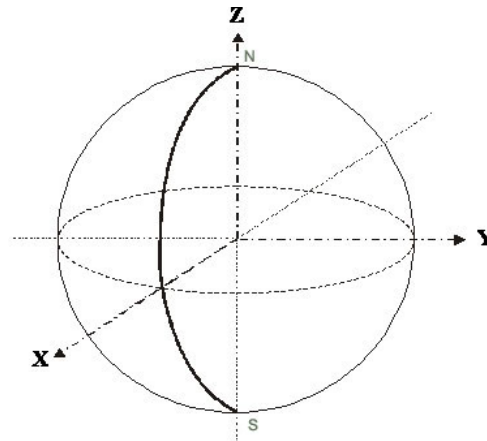
- expressed by **geographical coordinates** - **geographical longitude**
- **geographical latitude**





Point location through point transfer from warped earthborn body to the plane representation

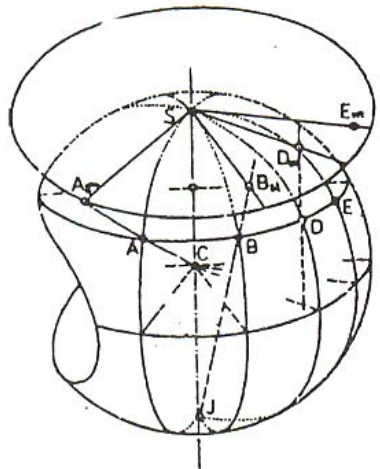
- **ETRS` 89** (European Terrestrial Reference System 1989)
- **S 42** (Pulkovo 1942) - reference frame for countries of former Warsaw Pact
- **WGS** (World Geodetic System) reference systems (GPS technologies)



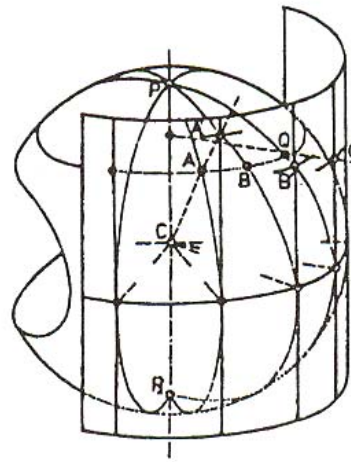


Cartographic representation

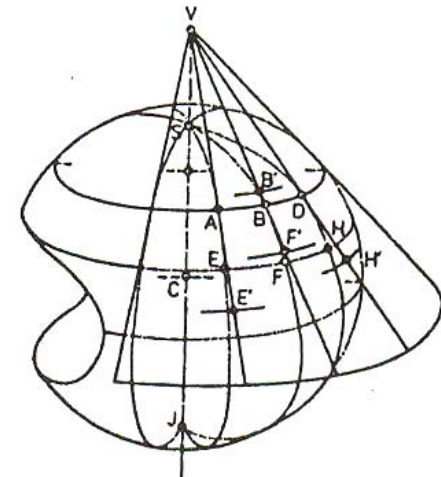
Classification by representation surface:



Azimuthal



Cylindrical

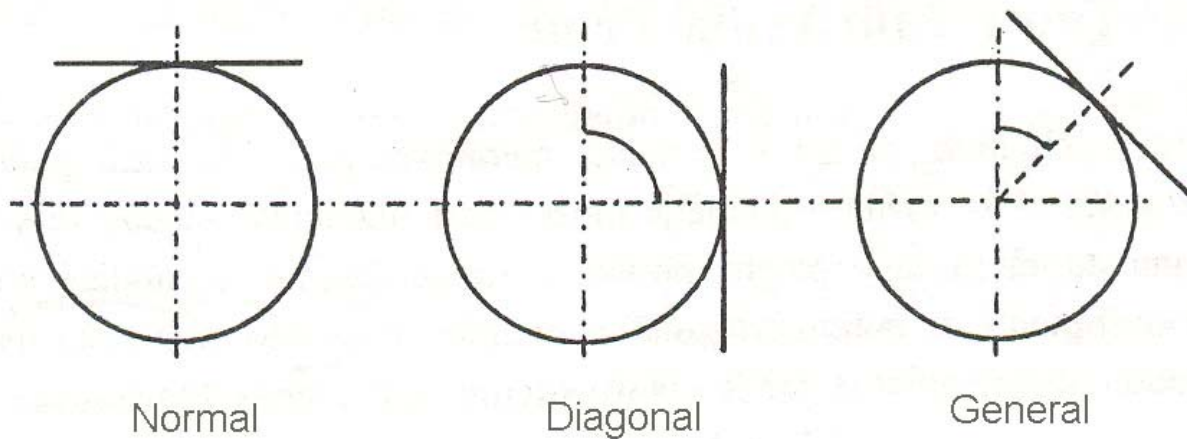


Conical



Cartographic representation

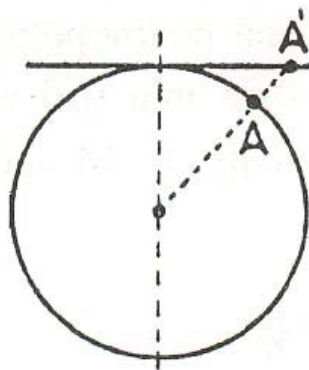
Classification by representation location:



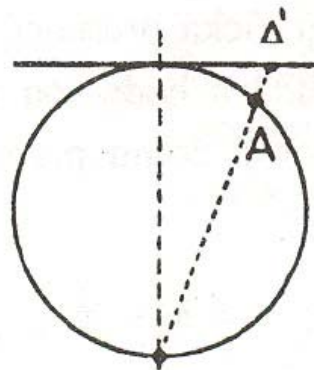


Cartographic representation

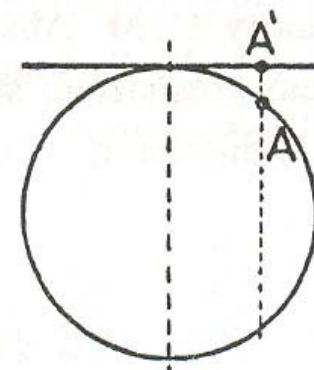
Classification in way of projection:



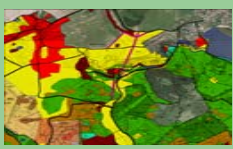
Gnomical



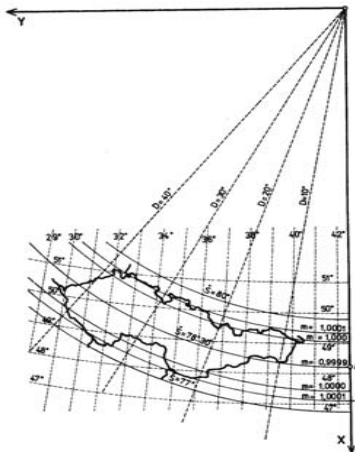
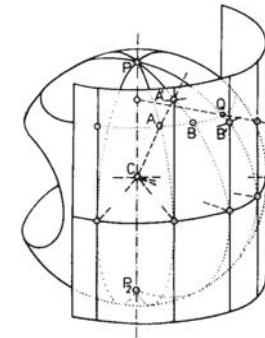
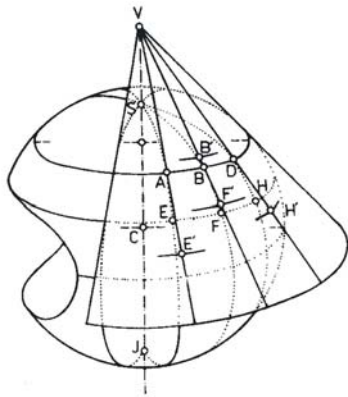
Stereographical



Orthographical



Difference between projection and transformation



1. $x_{11}, y_{11}, x_{12}, y_{12}$
2. $x_{21}, y_{21}, x_{22}, y_{22}$
3. $x_{31}, y_{31}, x_{32}, y_{32}$
-
-
-
- n. $x_{n1}, y_{n1}, x_{n2}, y_{n2}$



2. Transformations

Analytical transformation - geographical coordinates transformation to orthogonal plane coordinates

Numerical transformation - coordinates transformation between orthogonal plane reference systems



Numerical transformation

In practical GIS applications, there are used 2 methods:

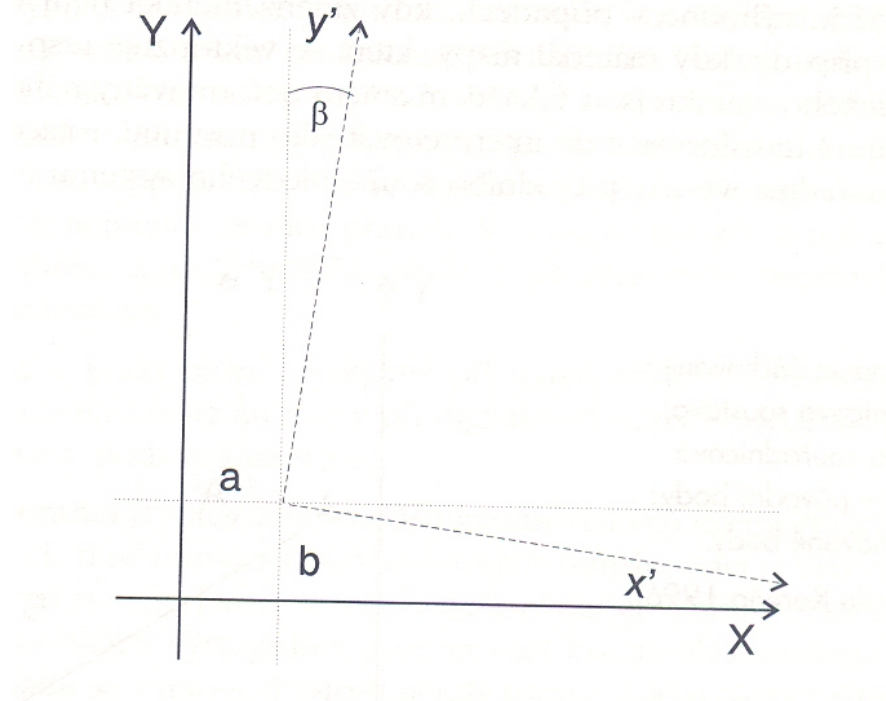
Linear conformal transformation (Helmert`s transformation)

Polynomic transformation



Linear conformal transformation

- suitable for transformation between reference systems that are moved, rotated to each other and also in the both reference axis direction have in equal proportion transformed scale





Linear conformal transformation

- is defined by equations:

$$\begin{aligned}x' &= (m * x * \cos(\beta) + m * y * \sin(\beta)) + a \\y' &= (-m * x * \sin(\beta) + m * y * \cos(\beta)) + b\end{aligned}$$

- in case of 2 pairs reference points (x_1, y_1) , (x_2, y_2) given in original and (x_1', y_1') , (x_2', y_2') in new reference system, the coefficients of transformation equations are calculated:

$$\begin{aligned}m \cdot \cos(\beta) &= \frac{(x_2 - x_1) \cdot (y_2' - y_1') - (y_2 - y_1) \cdot (x_2' - x_1')}{(x_2' - x_1') \cdot (x_2' - x_1') + (y_2' - y_1') \cdot (y_2' - y_1')} \\m \cdot \sin(\beta) &= \frac{(x_2 - x_1) \cdot (x_2' - x_1') + (y_2 - y_1) \cdot (y_2' - y_1')}{(x_2' - x_1') \cdot (x_2' - x_1') + (y_2' - y_1') \cdot (y_2' - y_1')}\end{aligned}$$



Linear conformal transformation

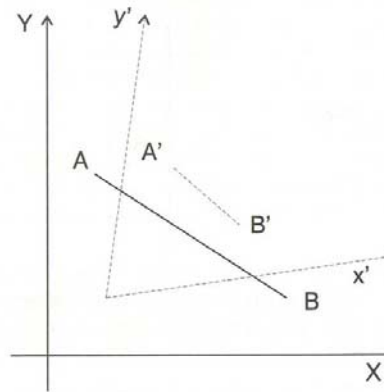
Due to optimal assessment of transformation parameters, it is better to use more reference points in calculation.

Coefficients values are then calculated with the „least square analysis“.



Polynomic transformation

- in difference to linear transformation the individual coordinates are transformed independently. Corrections in every reference axis direction are conducted separately. It is very useful in case when the scale transformation is not equal in all directions.



- The simplest case of polynomic transformation is **affine transformation** that is defined by:

$$\begin{aligned}x' &= a * x + b * y + c, \\y' &= d * x + e * y + f\end{aligned}$$



Polynomic transformation

If the deformation of transformed map reference system has more complicated progress or local character, it is more advantageous to use polynomic transformation of higher level.

Polynomic transformation of n^{th} level:

$$x' = \sum_{m=0}^n \sum_{i=0}^m a_{m,i} x^i y^{m-i},$$

$$y' = \sum_{m=0}^n \sum_{i=0}^m b_{m,i} x^i y^{m-i}$$



Polynomic transformation

Specially prerequisite for affine type of transformation ($n=1$) are 3 pairs of points at least. But it is recommended not to use minimal number of points.

For calculation of transformation equation coefficients are required at least

$$N_n = \frac{n^2 + 3n + 2}{2} \quad \text{pairs of points.}$$

Coefficients of transformation equations are calculated by the „least square analysis“



3. Resampling

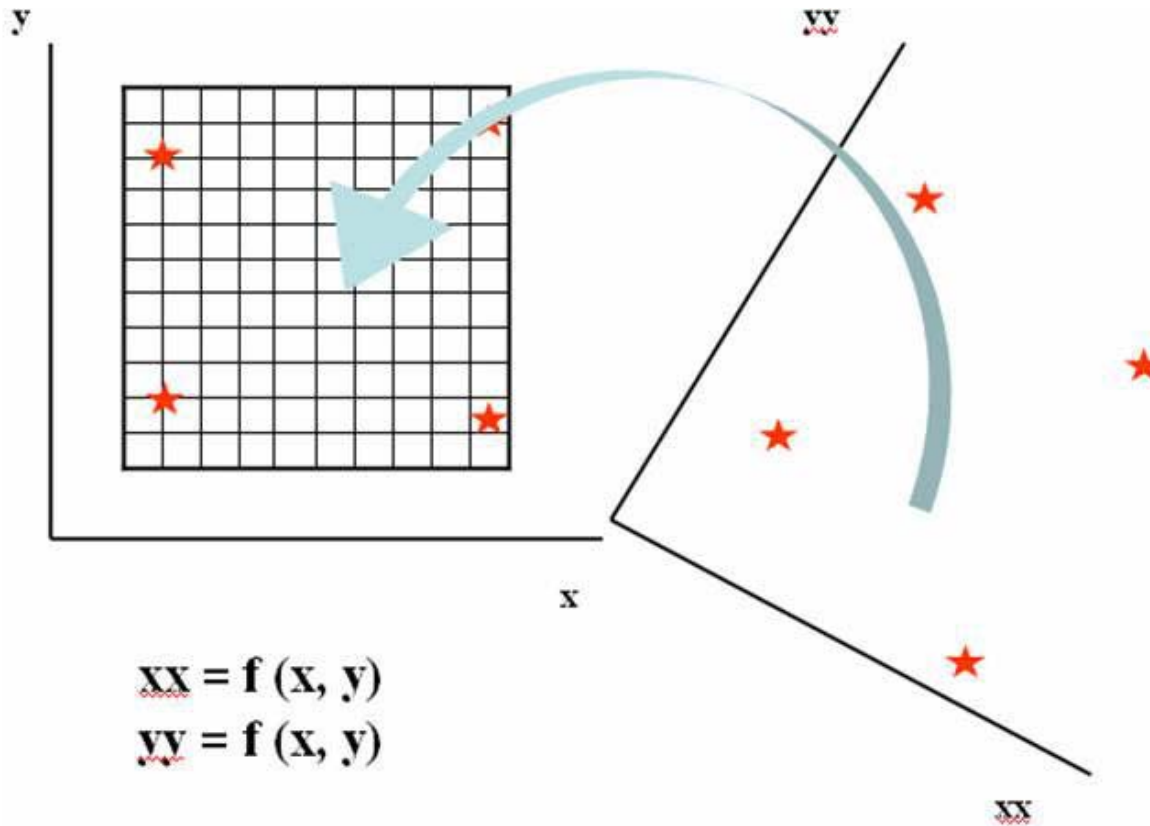
In case of raster representation it can have character of linear or polynomic transformation.

From practical point of view are these procedures individualized primarily by co-ordination data of different resources, reference system transformation, changing spatial resolution of representation, setting of raster representation, ortho photo or other remote sensing material on other raster representation or on map.

In process of resampling, in accordance with transformation equations, there is calculated location of each pixel centre of new representation in reference system of input representation – transform itself into it. After identification of of pixel centre location is possible to assign or calculate for it attribute value from values stored in original representation.



Resampling – transformation equations calculation

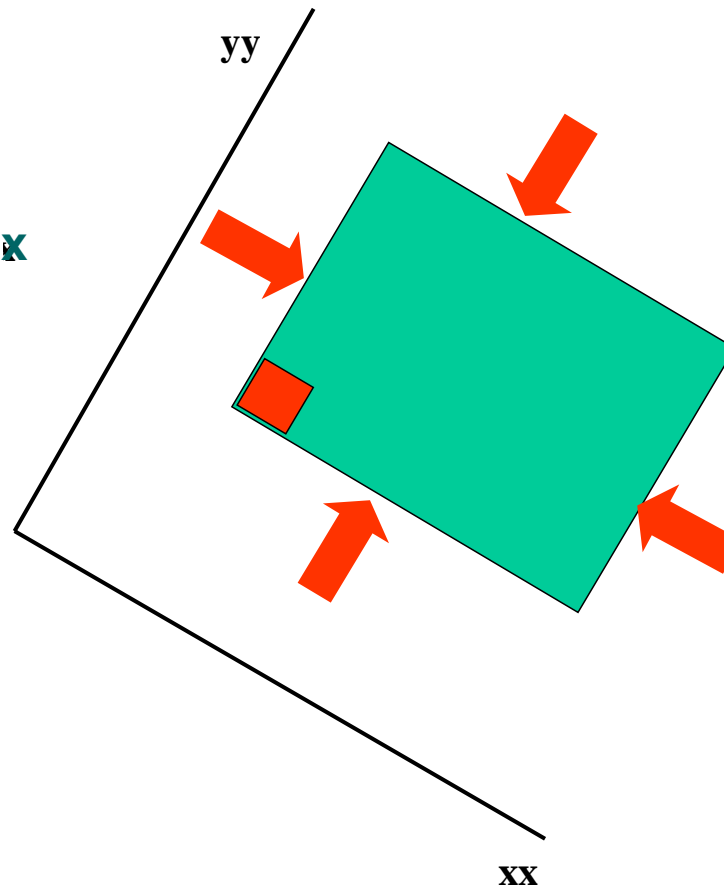




Resampling – geometric definition of target raster

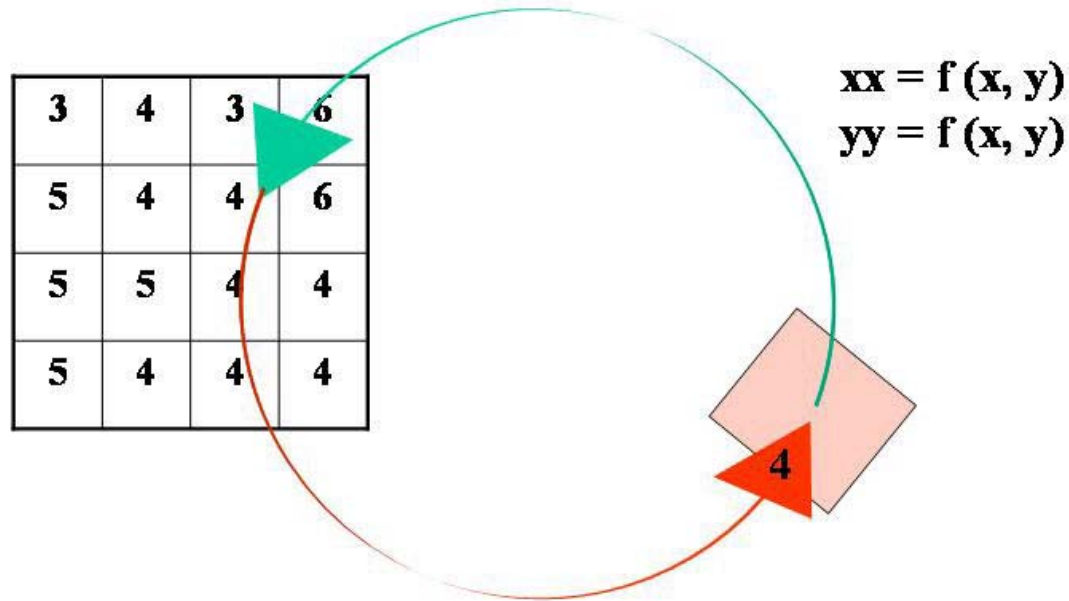
Space specification
 $xxmin, xxmax, yymin, yymin$

Resolution
 $\Delta xx, \Delta yy$





Resampling – assigning of original raster values to pixels (cells) of target raster





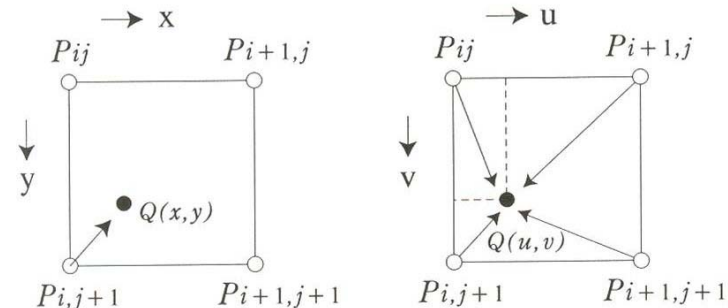
3. Resampling

There are 3 techniques to assign new value:

Nearest neighbor

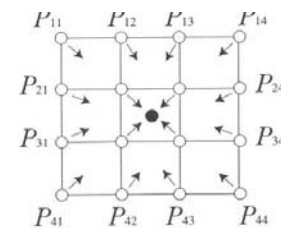
Bilinear interpolation

Cubic convolution



(a) Nearest Neighbor

(b) Bilinear

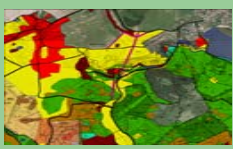


(c) Cubic Convolution



Nearest neighbor

- technique suitable mainly for qualitative data.
- input data are not changing against output ones.
- to the transformed location of output pixel centre is assigned attribute value stored in pixel of original raster.
- the disadvantage of this method is formation of stair stepped effect along image lines.



Bilinear interpolation

- there are identified 4 nearest pixel centres of original representation against transformed centre of output pixel.
- assigned value is calculated as mean value of 4 neighboring weighted distances.
- this method is suitable mainly for continuously changing values, e.g. surfaces, image functions.
- the disadvantage is smoothing of edges and loss of some extreme image values.



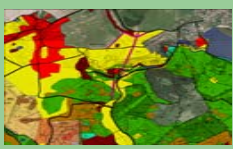
Cubic convolution

- is similar with bilinear interpolation, but the assigned value is calculated as distance weighted mean of 16 nearest values of input representation.

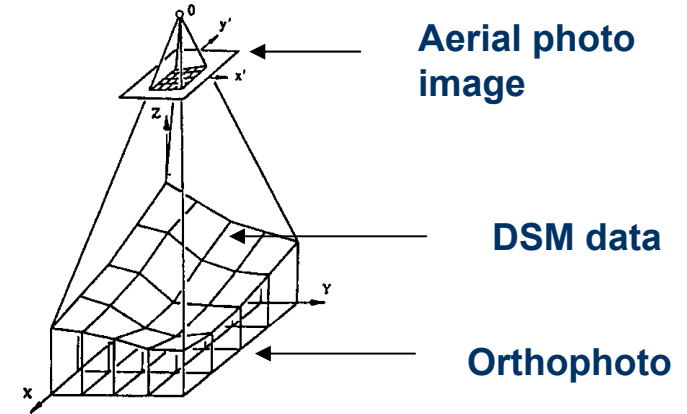


4. Orthorectification

- process which removes tilt and relief displacement in the aerial photographs to produce a relief map like ortho image.
- digital orthophotos can be generated using a digital photogrammetric system.
- Aeromap US (2000) defined a **digital orthophoto** as a „spatially corrected aerial photograph“ created by gaining a high resolution scan of a photograph and using special software to rectify the image through a rigorous mathematical model.
- secondary product of digital orthophoto creation is digital surface model.



Orthophoto,
radiometric corrections



Digital differential redrawing



Mosaic



Orthophoto map



References

Tuček, J. 1998. Geographical Information Systems – Principles and practice. Computer Press Brno. [In Czech]

Žíhlavník, Š. 1999. Geodesy and photogrammetry in forestry. Technical University in Zvolen. [In Slovak]