CENN Caucasus Environmental NGO Network

Training Course

Remote Sensing – Basic Theory & Image Processing Methods

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Geometric Operations

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- Two dimensional approaches
  - Georeferencing
  - Geocoding
- Three dimensional approaches
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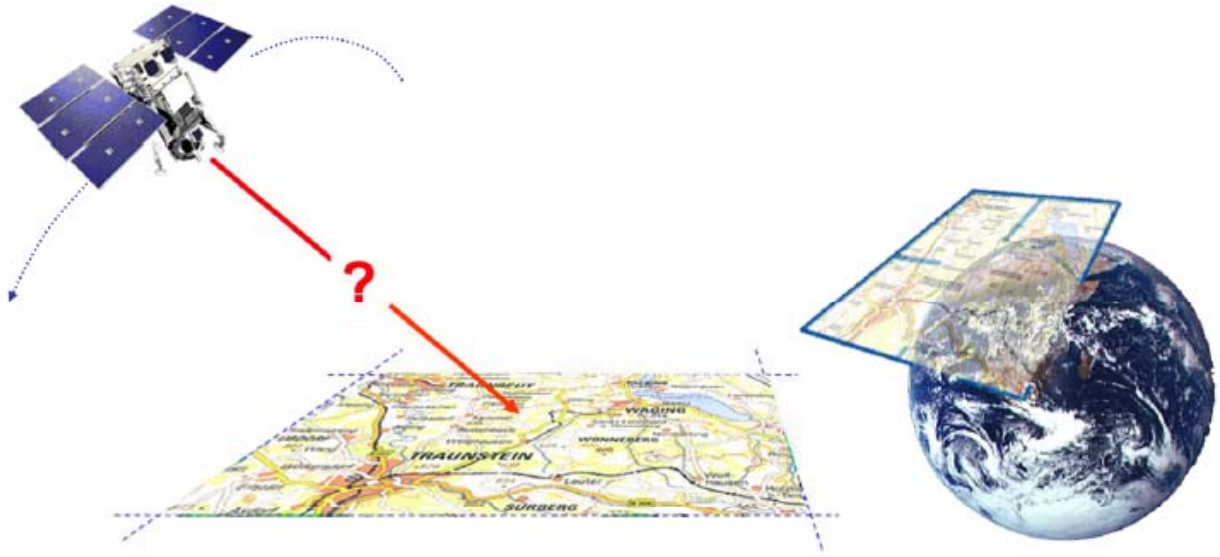
Why correct images for geometric distortions ?

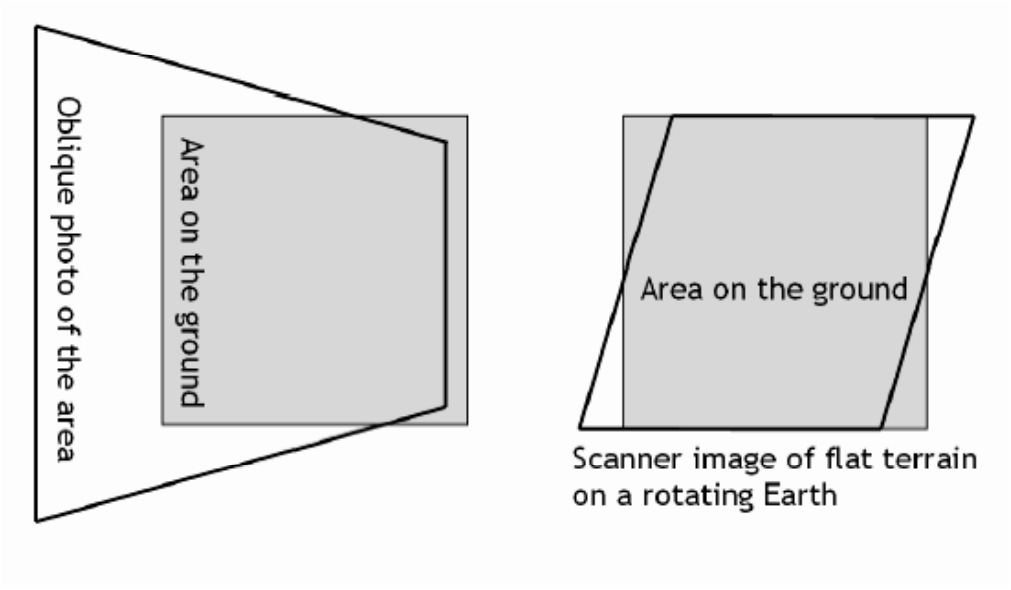


Why correct images for geometric distortions ?

1. **To get 2-dimensional (*x, y*) and 3 dimensional (*x, y, z*) coordinate information**
2. **To visualize the image data in a GIS environment (backdrop image)**
3. **To merge ("fuse") different types of image data, for instance in a GIS or multi-temporal analysis ("monitoring")**

Elementary image distortions

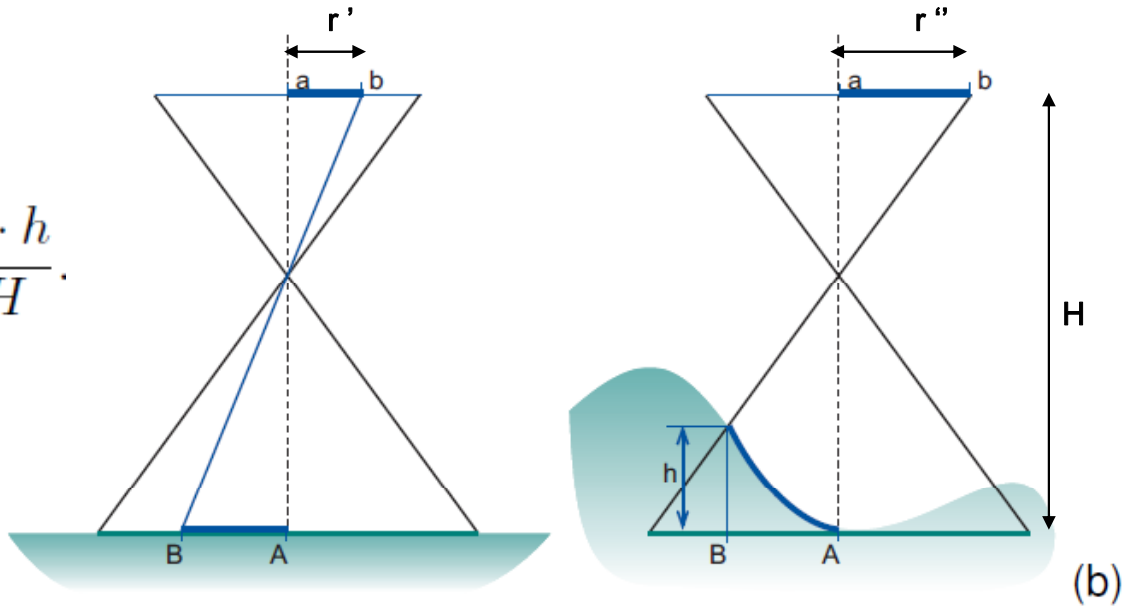
Each sensor-platform combination can have its own type of geometric image



Elementary image distortions

Relief displacement shows up specifically in camera images of large scale

$$\delta r = \frac{r \cdot h}{H}.$$



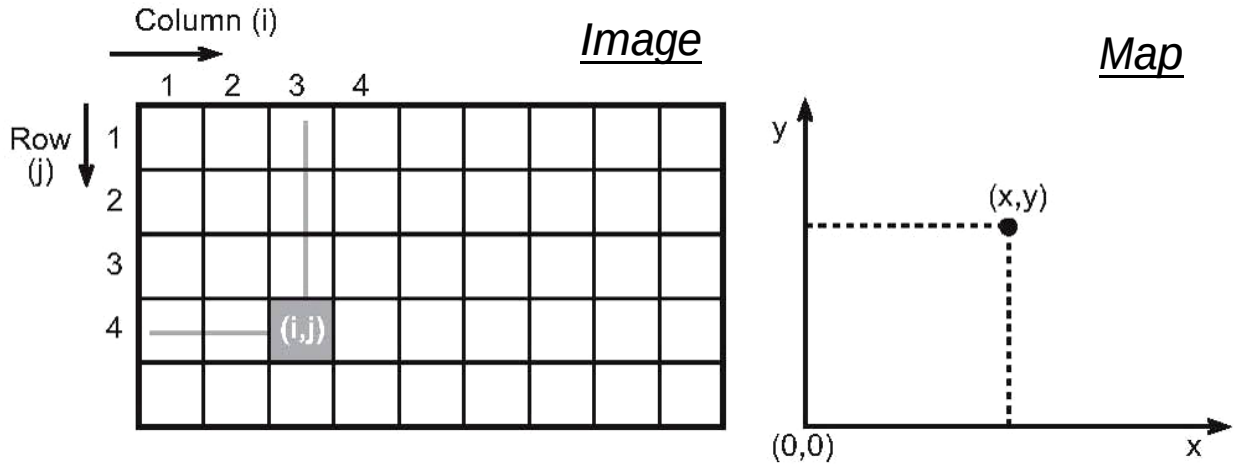
Elementary image distortions

Relief or "height" displacement – example centre of Enschede

Two dimensional approaches

To be used if relief displacement can be neglected:
(1) flat terrain or (2) space imagery with low resolution

The objective is to relate the *image* coordinate system to a specific *map* coordinate system



Georeferencing

Two steps approach:

1. **Selection of the appropriate type of *transformation***
2. **Determination of the *transformation parameters***

***A geometric transformation* is a function that relates the coordinates of two systems:**

for instance map *x*, *y* to image: *i*, *j*

The *type* of transformation to be used depends mainly on the type of sensor-platform

Types of transformation

Projective transformation : **corrects for pitch and roll in for instance aerial photographs**

Polynomial transformation: **1st, 2nd to nth order.**

In most situations 1st order adequate

$x = a + bi + cj$ $\quad$ x, y : **map coordinates**

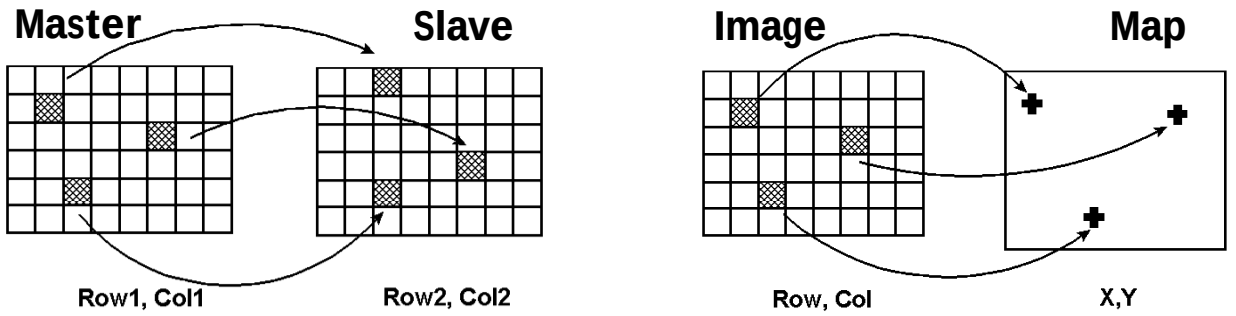
$y = d + ei + fj$ $\quad$ i, j : **image coordinates**

The six transformation parameters (a…. f) can be determined by *Ground Control Points (GCPs)*

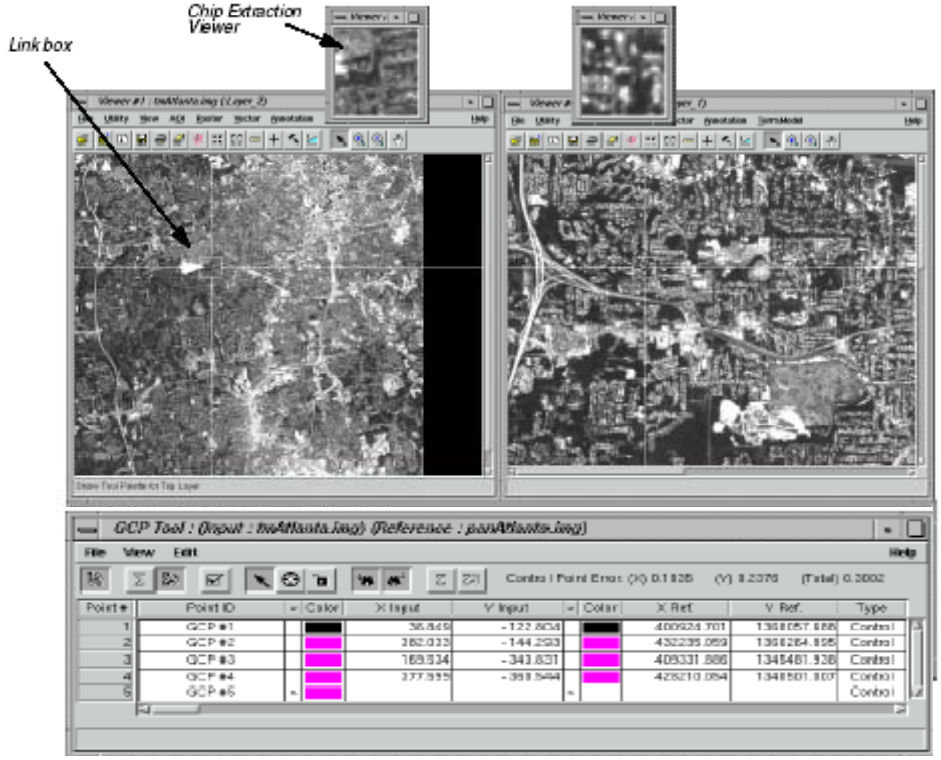
Ground Control Points (GCPs)

Ground Control Points **(GCPs): points that can be clearly identified both in the image and in a source with the required map projection.**

Sources: (1) topographical map, (2) already rectified image, (3) GPS field points !

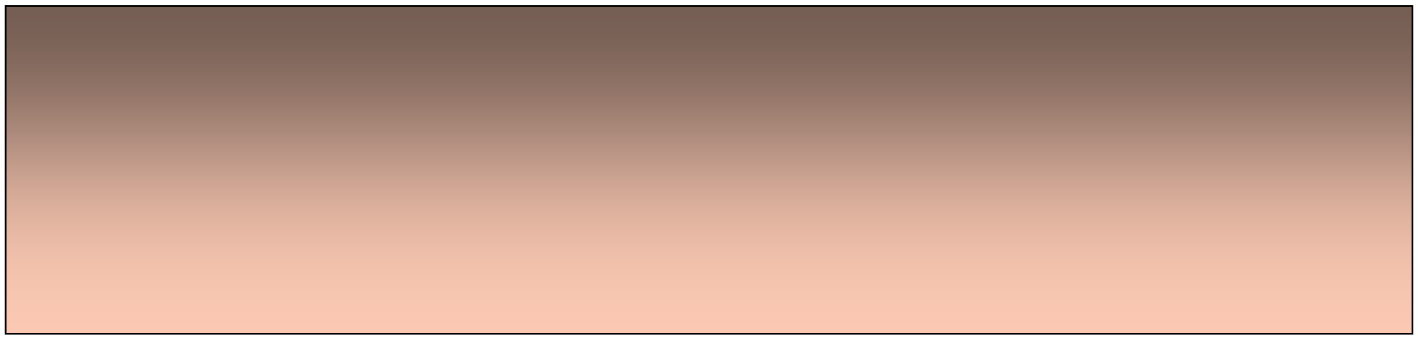


Rectification in ERDAS Imagine (image-to-image)



Accuracy of the transformation

Root Mean Square Error (RMS) : **calculates a mean value from the individual residuals, both in *x* and *y* direction.**



Accuracy of the transformation

GCP	i	j	x	y	x_c	y_c	d_x	d_y
1	254	68	958	155	958.552	154.935	0.552	-0.065
2	149	22	936	151	934.576	150.401	-1.424	-0.599
3	40	132	916	176	917.732	177.087	1.732	1.087
4	26	269	923	206	921.835	204.966	-1.165	-1.034
5	193	228	954	189	954.146	189.459	0.146	0.459

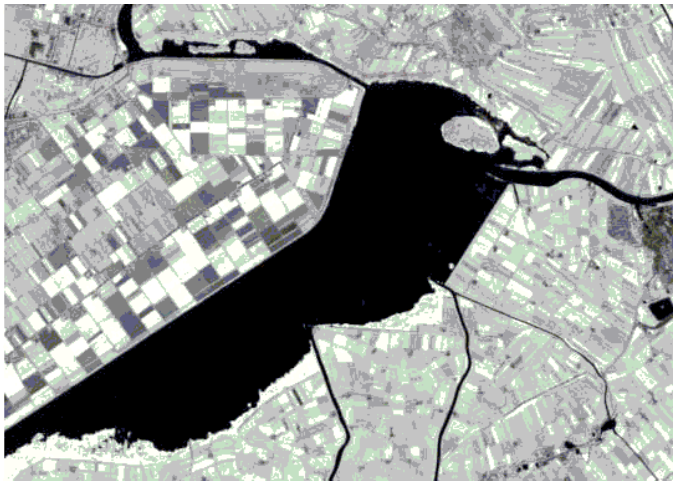
$$m_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n} dx_i^{\,2}}$$

$$m_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n} dy_i^{\,2}}$$

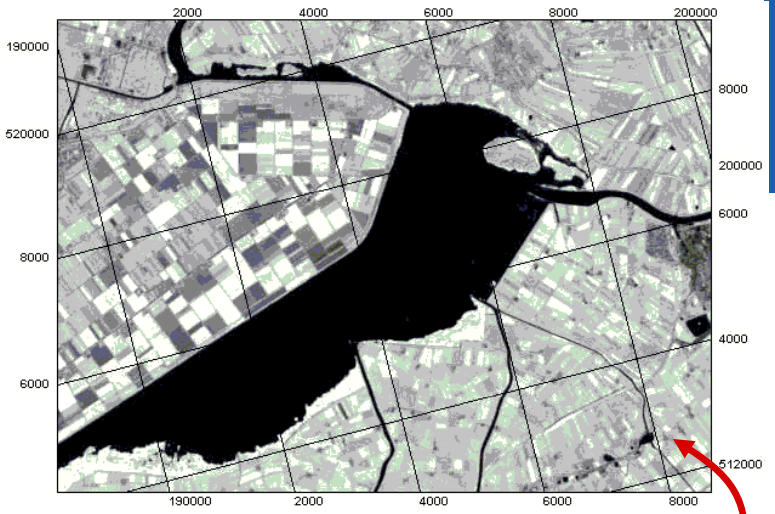
Root Mean Square Error

$$m_{total}\,(RMSE) = \sqrt{m_x^{\,2} + m_y^{\,2}}$$

Images – Original and geo-referenced



Original image



Geo-referenced image

Flevoland - IJssel delta, The Netherlands

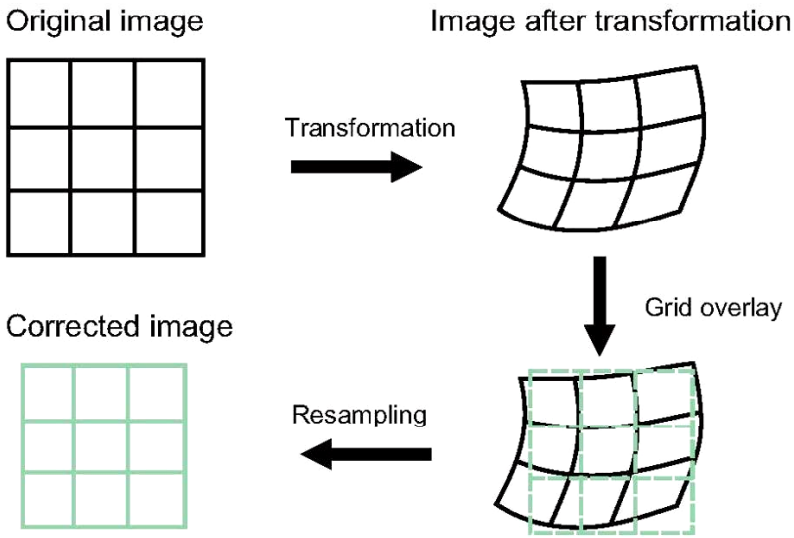
Co-ordinates

Geocoding -> Resampling

Geocoding **is geo-referencing with subsequent** *Resampling* **of the raster image.**

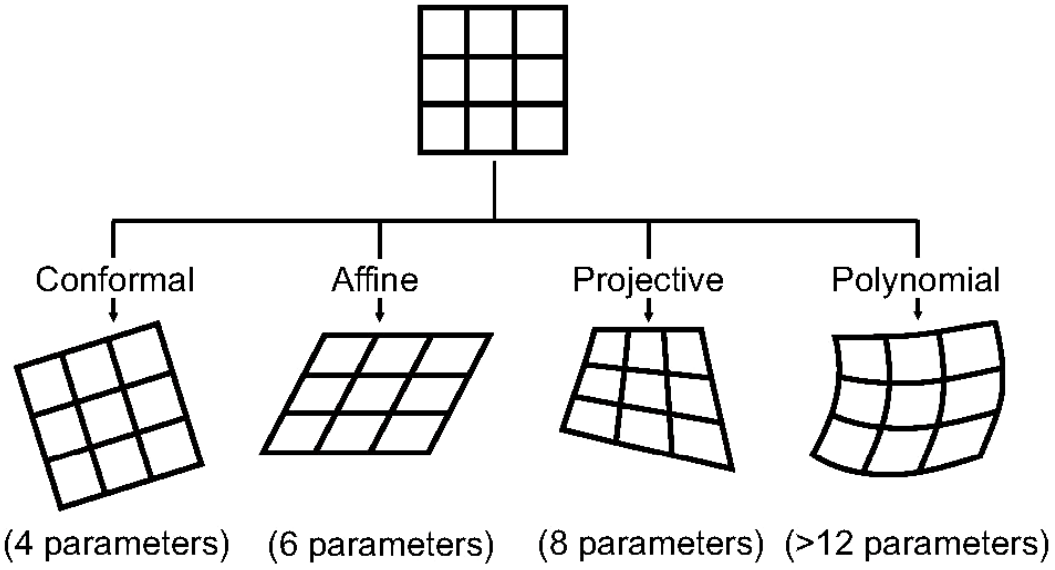
Two step approach:

1. *Projection* **of raster onto the original image using the** *transformation* **parameters**
2. *Resampling* **of raster image**

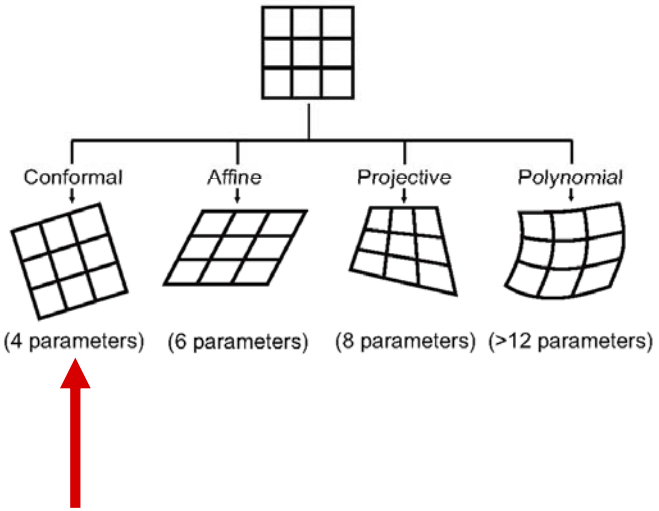


Transformation types for Geo-coding

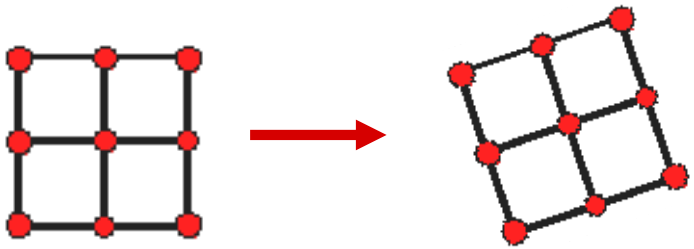
The types of transformation frequently used in RS, based on their increase in complexity:



Transformation types for Geo-coding

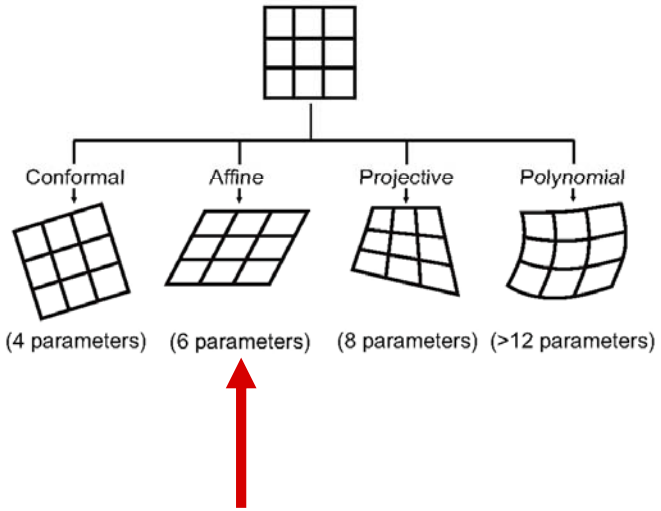


Conformal (4 parameters):

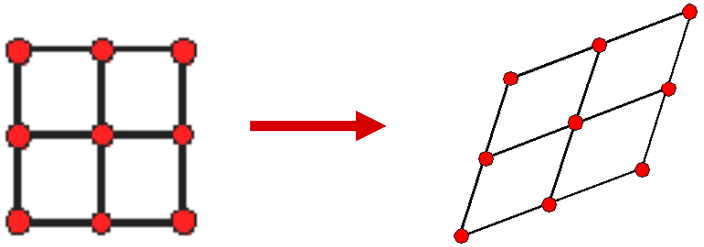


Rotation, scaling,
preservation of angles (shape)

Transformation types for Geo-coding

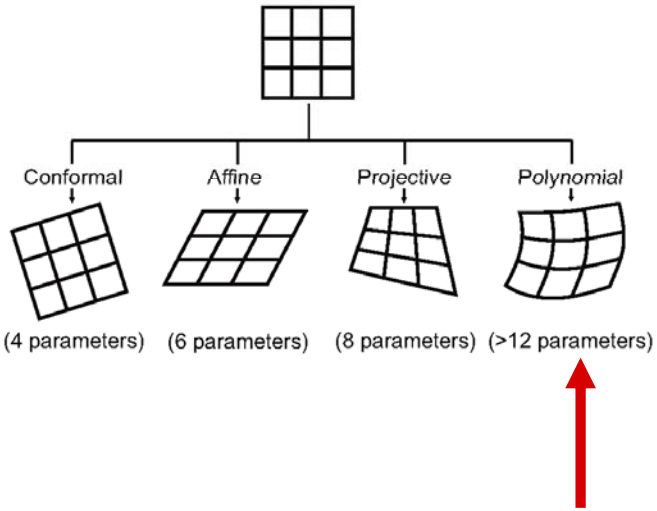


Affine (8 parameters):

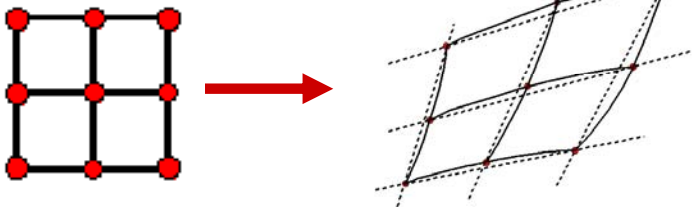


Rotation, scaling, preservation of parallels

Transformation types for Geo-coding



Polynomial (2nd order):



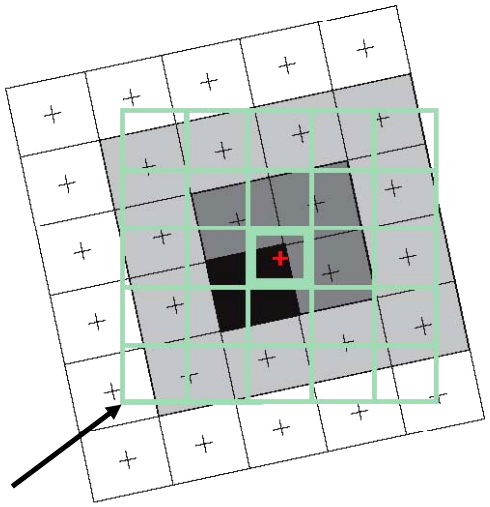
Rotation, scaling,
no preservation of parallels
straight lines become curved

Resampling types for raster image

As the orientation and size of the original and output raster image are different, *interpolation* is required for each pixel.

Resampling methods:

- **Nearest Neighbour**
- **Bilinear Interpolation**
- **Cubic Interpolation**



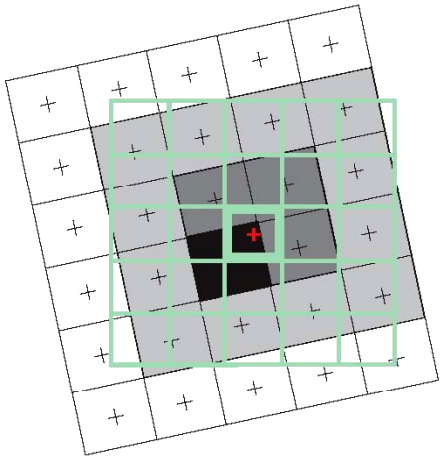
Green line original image

Nearest Neighbour

Bilinear Interpolation

Cubic Interpolation

Resampling types for raster image

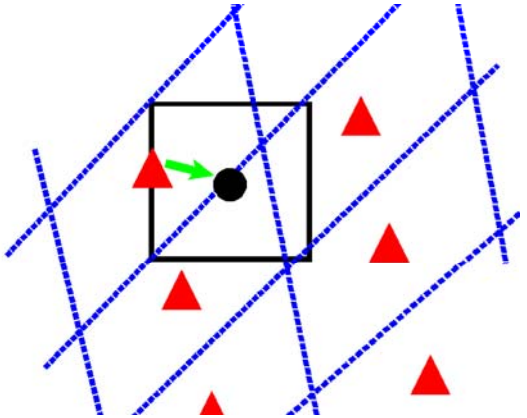


Nearest Neighbour

Bilinear Interpolation

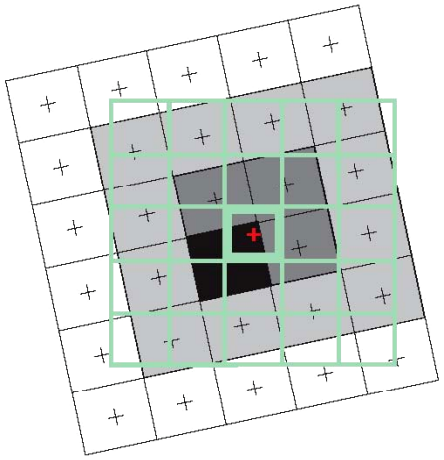
Cubic Convolution

Nearest Neighbour



Pixel value(s) retained !

Resampling types for raster image

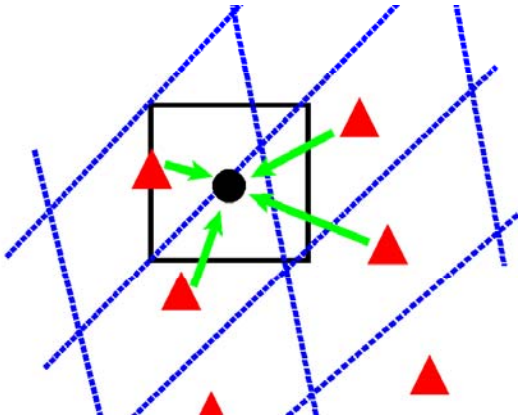


Nearest Neighbour

Bilinear Interpolation

Cubic Convolution

Bilinear Interpolation

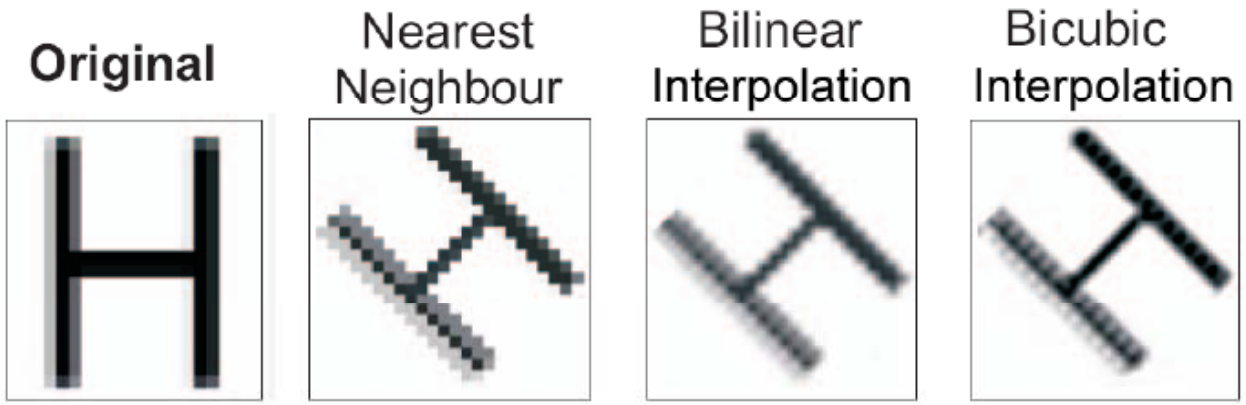


Smooth result

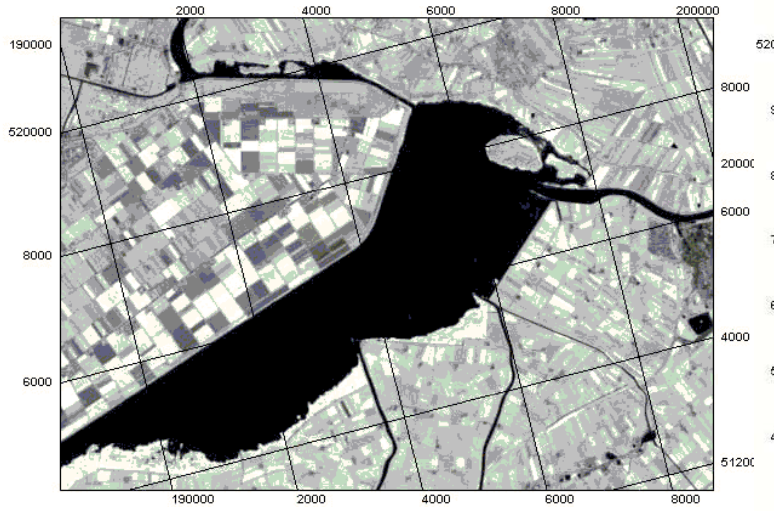
Choice of resampling types

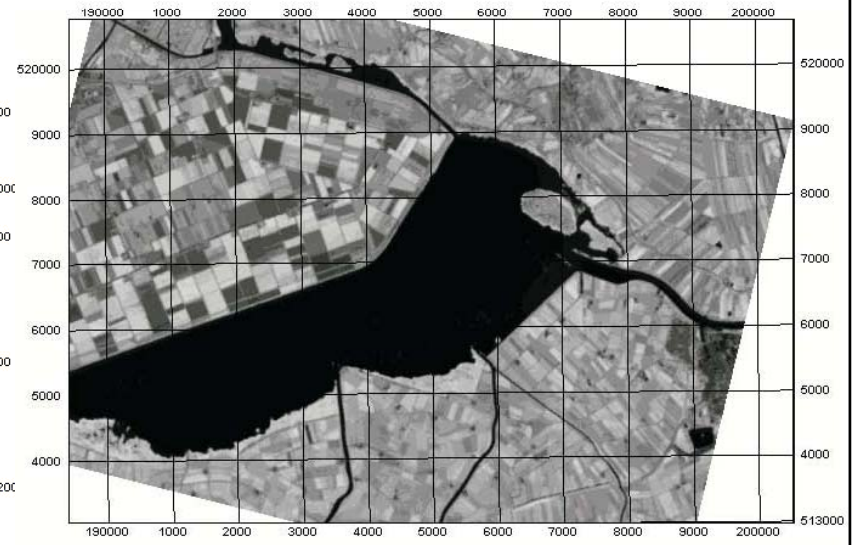
Spectral <> Spatial accuracy

- **Nearest neighbour : spectral information retained**
- **Cubic Interpolation : smoother spatial information**



Images – Geo*referenced* vs. Geo*coded*



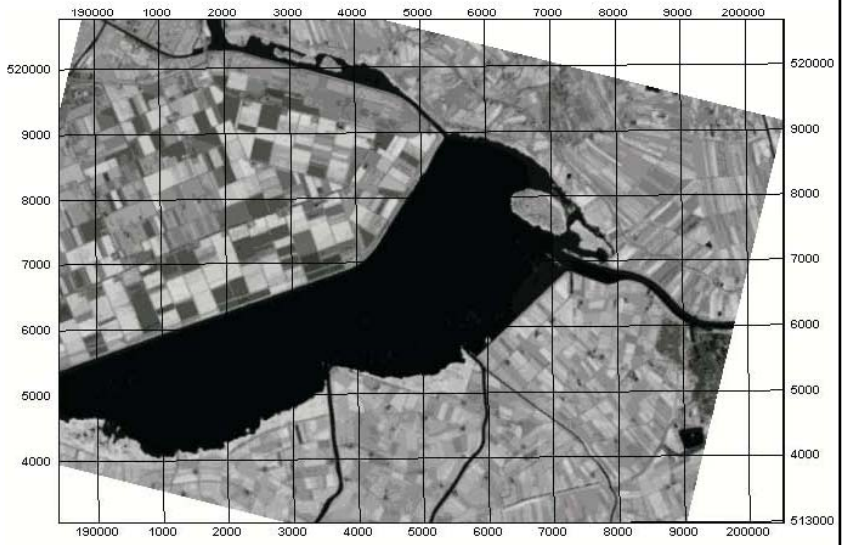


Geo*referenced* image

Geo*coded* image

Flevoland - IJssel delta, The Netherlands

Images – Topomap vs . Geo*coded* image



Topographical map **Geo*coded* image**

Flevoland - IJssel delta, The Netherlands

Three-dimensional approaches (1)

3D correction or information extraction

- **Monoplotting**

  Using a DEM to calculate terrain coordinates – no re-sampling

- **Ortho-image production**

  Resampling of an image into map geometry taking terrain relief into account

- **Stereo-restitution**

  Use of two images ('stereo-pair') to extract 3D information

- **Orietation**

  Results in formula to calculate image coordinates (**X, Y**) from terrain coordinates (*x, y, z*)

Three-dimensional approaches (2)

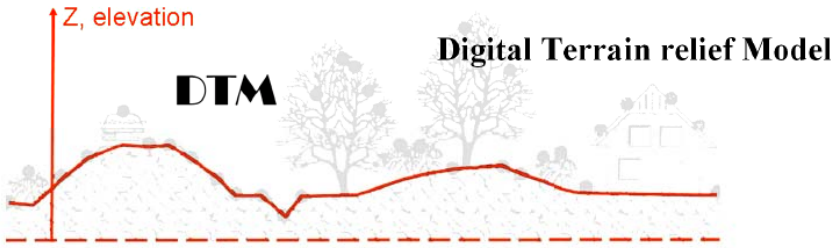
2D geospatial data describes the horizontal position of terrain features : *X, Y* coordinates

Elevation differences in the scene cause relief displacement

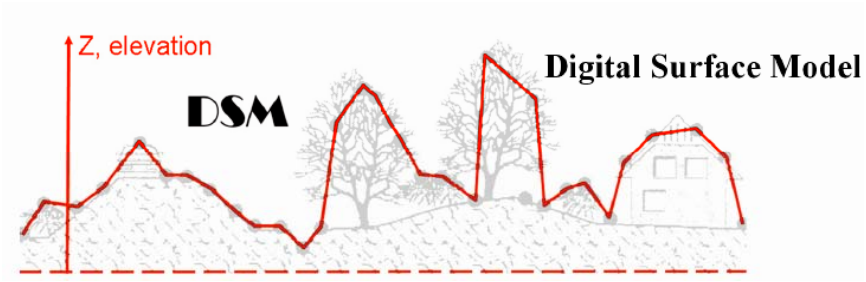
3D geospatial data also considers also vertical position of terrain features (for instance height above sea level) : *X, Y, Z* coordinates

Three-dimensional approaches (3)

Digital Terrain relief Model (DTM): model of the shape of the ground surface

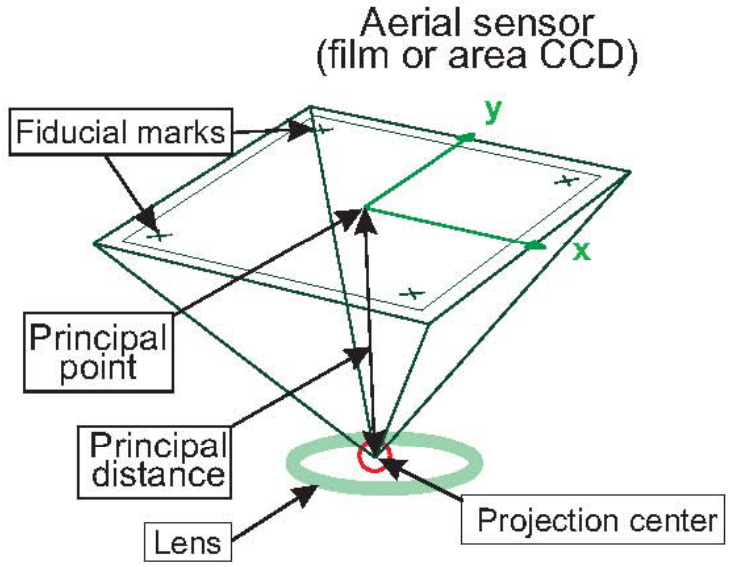


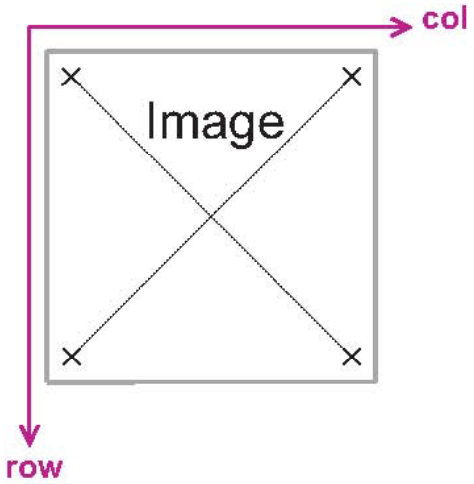
Digital Surface Model (DSM): model of shape of the surface, including vegetation, infra-structure, etc.



Three-dimensional approaches (4)

Interior orientation: **reconstruction of the position of the projection centre of sensor: AP-> Principal Point**





Three-dimensional approaches (5)

Exterior orientation: **Reconstruction of position and attitude / inclination of the sensor with respect to terrain coordinate system.**

Parameters:

1. **Indirect camera orientation:** **Measurements of GCP in the terrain (X, Y and Z)**
2. **Direct camera orientation:** **Orientation of the sensor itself (position and attitude) by GPS and Inertial Measurement Unit IMU**
3. **Integrated Camera orientation:** **Combi of 1. and 2.**

Three-dimensional approaches (6)

Exterior orientation:

RPC : Rational Polynomial Coefficient

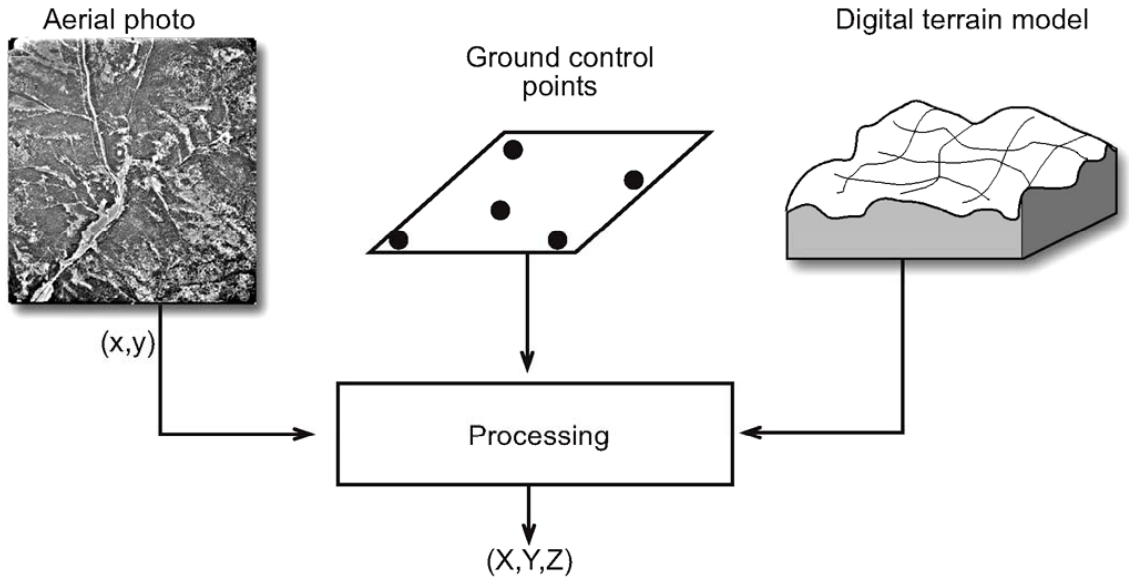
Gives approximation if of relationship between image coordinates of an entire frame and terrain coordinates.

Can be used by RS software, such as

ERDAS Imagine

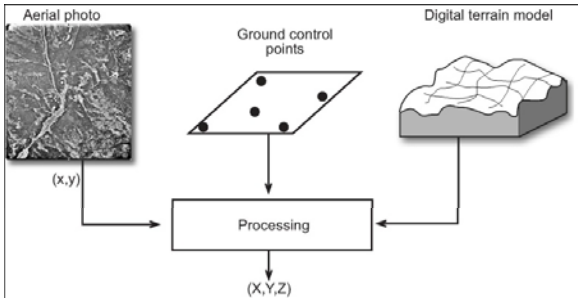
Three-dimensional approaches (7)

Monoplotting: **Using a DTM to calculate terrain coordinates – no resampling needed**

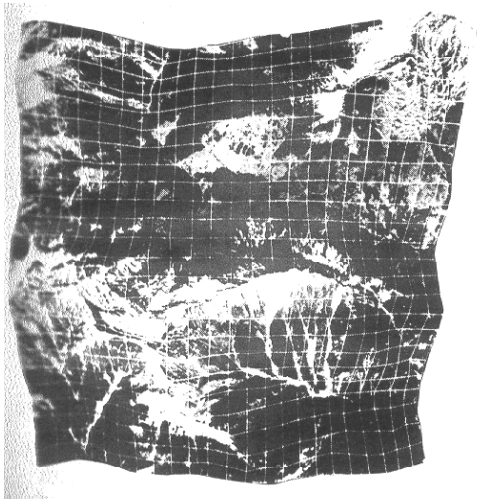


Three-dimensional approaches (8)

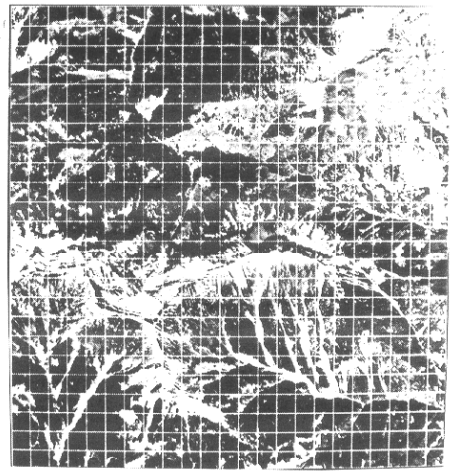
Orthophoto: **Resampling of an image into map geometry taking terrain relief into account**



Monoplotting
+
Resampling



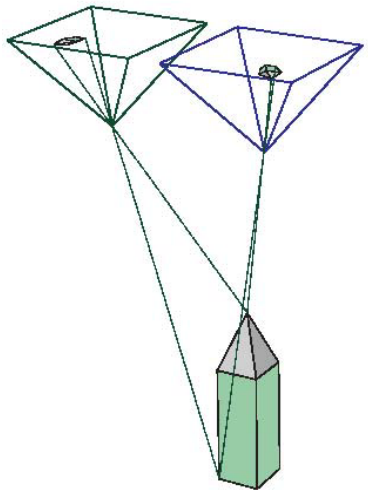
On the original aerial photo the map grid is distorted

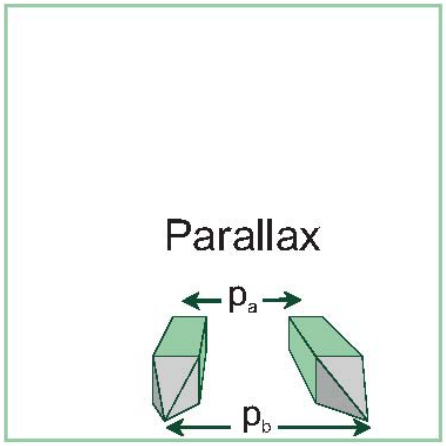


Geometrically correct orthophoto

Three-dimensional approaches (9)

Stereo restitution: **Use of two images ('stereo-pair') to extract 3D information. For measurements use is made of parallax**





Summary ...(1)

- **To correct images 2 dimensionally for distortions:**
  1. Georeferencing
  2. Geocoding
- **Use of appropriate Transformation**
- **Use of Ground Control Points (GCP) from GPS or Topographical map**
- **Transformation types:**
  - Conformal: preservation of angles
  - Affine: preservation of parallels
  - Polynomical (2nd order)

Summary ...(2)

- **Image resampling methods:**
  - Nearest Neighbour : pixel values retained
  - Bilinear Interpolation: "smooth" result"
  - Cubic convolution
- **Three dimensional approaches for correction of image distortion (for instance AP)**
  - Internal & external orientation
  - Monoplotting
  - Use of DEM

Questions