Lecture 8

based on W 3 of prof R. Tokarczyk

Image rectification

Projection 2D on 2D and projection 3D on 2D

Geometric transformation

Orthophotography: rules, orthoimage and orthophotomap, resampling

Topographical maps

Image rectification

Image rectification – image processing to the metric form and presented in terrain coordinate system

Rectification result is called by photographical map, because map content is in photographical form by the geometry is changed – new artificial image is generated, like we obtain in orthogonal projection

Photographical maps are categorized by photomaps and orthophotomaps, depending of the rectification method

If terrain is flat or almost flat projective transformation is applied and the result is called photomap

In the case if the applying of DTM is needed, because of the map accuracy, more complex process is involved, we called it orthophotorectification, and the result - orthophotomap

KP

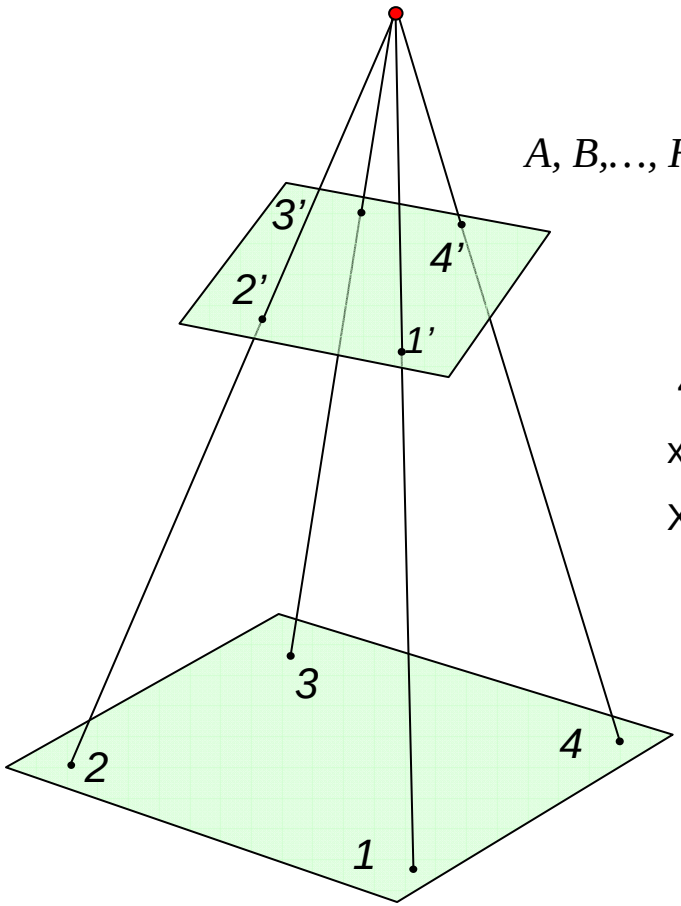
Mapping 2D on 2D
– projective transformation

$$x = \frac{AX + BY + C}{DX + EY + 1}$$

$$y = \frac{FX + GY + H}{DX + EY + 1}$$

simple

$A, B, \ldots, H$ (8)



x,y in any image coordinate system

5 pont and nexts are additional

Analytical relations

Linearization needed

unknowns

needed for unknowns determination at least

4 points

x,y

X,Y

3 points

x,y

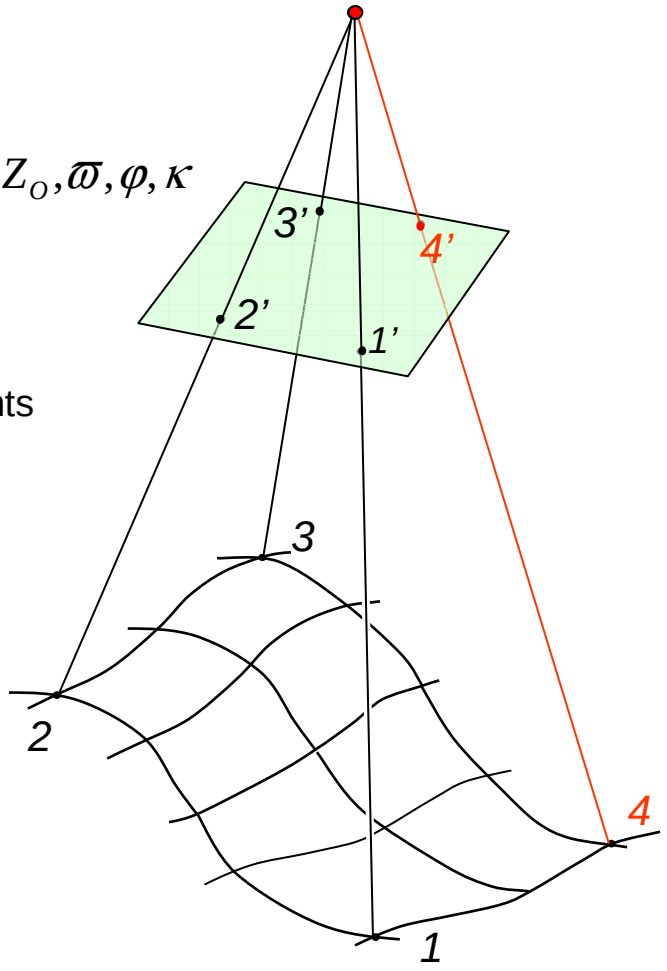
X,Y,Z

mapping 3D on 2D –
With collinearity equations

$$x = -c\frac{a_{11}(X - X_O) + a_{21}(Y - Y_O) + a_{31}(Z - Z_O)}{a_{13}(X - X_O) + a_{23}(Y - Y_O) + a_{33}(Z - Z_O)}$$

$$y = -c\frac{a_{12}(X - X_O) + a_{22}(Y - Y_O) + a_{32}(Z - Z_O)}{a_{13}(X - X_O) + a_{23}(Y - Y_O) + a_{33}(Z - Z_O)}$$

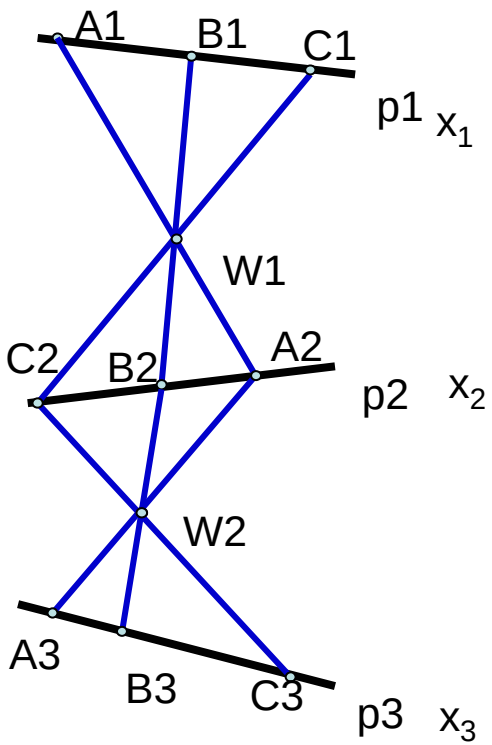
(6) $X_O, Y_O, Z_O, \varpi, \varphi, \kappa$



x,y in fiducial coordinate system

4 point and nexts are additional

Przekształcenia rzutowe
Prostej na prostą

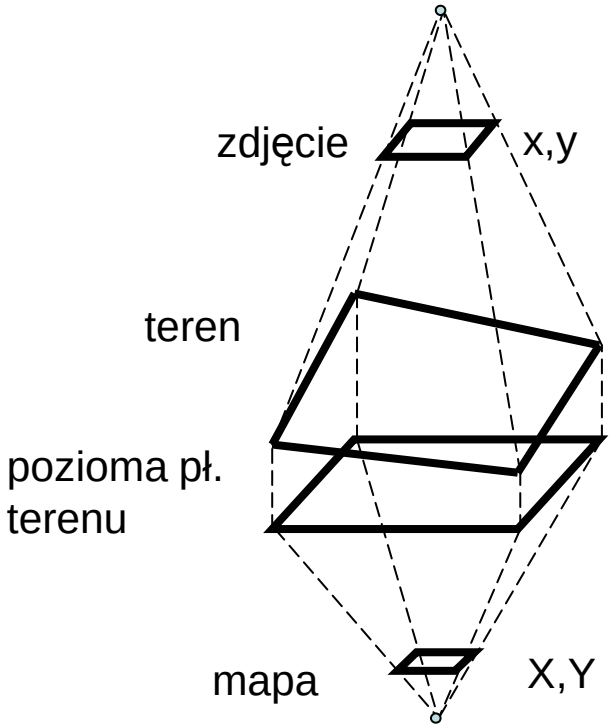


$$x_1 = \frac{A_2 x_2 + B_2}{C_2 x_2 + 1}$$

$$x_1 = \frac{A_3 x_3 + B_3}{C_3 x_3 + 1}$$

Wzajemną rzutowość określa trójka punktów homologicznych

Płaszczyzny na płaszczyznę



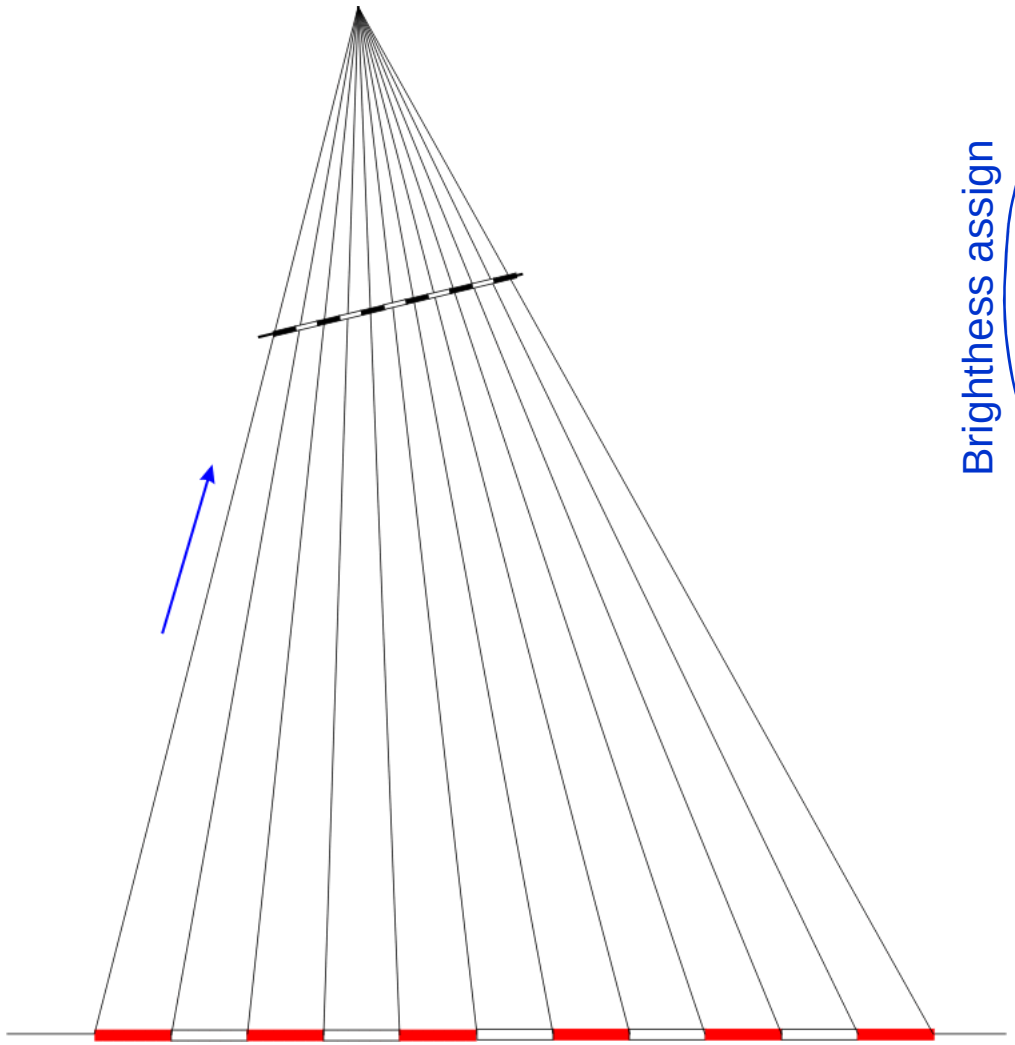
$$x = \frac{AX + BY + C}{DX + EY + 1}$$

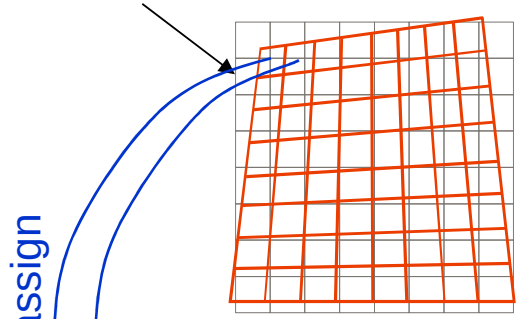
$$y = \frac{FX + GY + H}{DX + EY + 1}$$

Wzajemną rzutowość określa czwórka punktów homologicznych (odpowiadających sobie)

Projective transformation

Digital image B

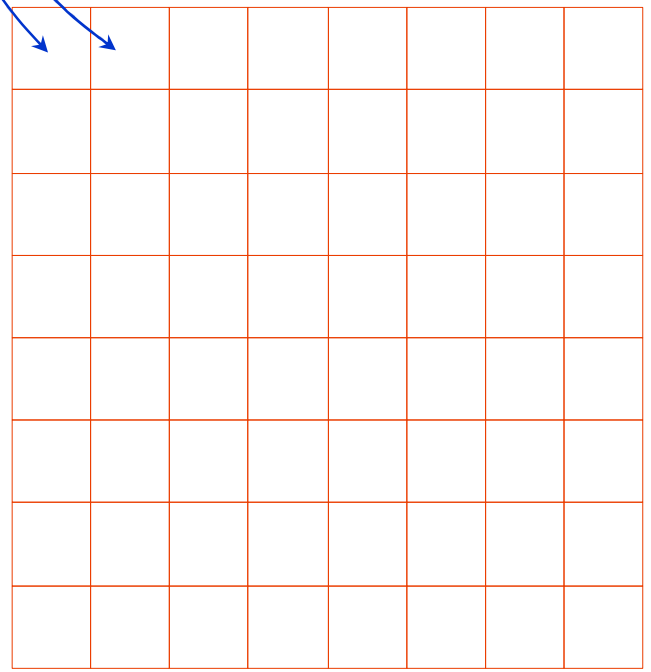




Photomap on the image plane

Brighthess assign

(digital image A)



Digital fotomap generation

Geometric image transformation

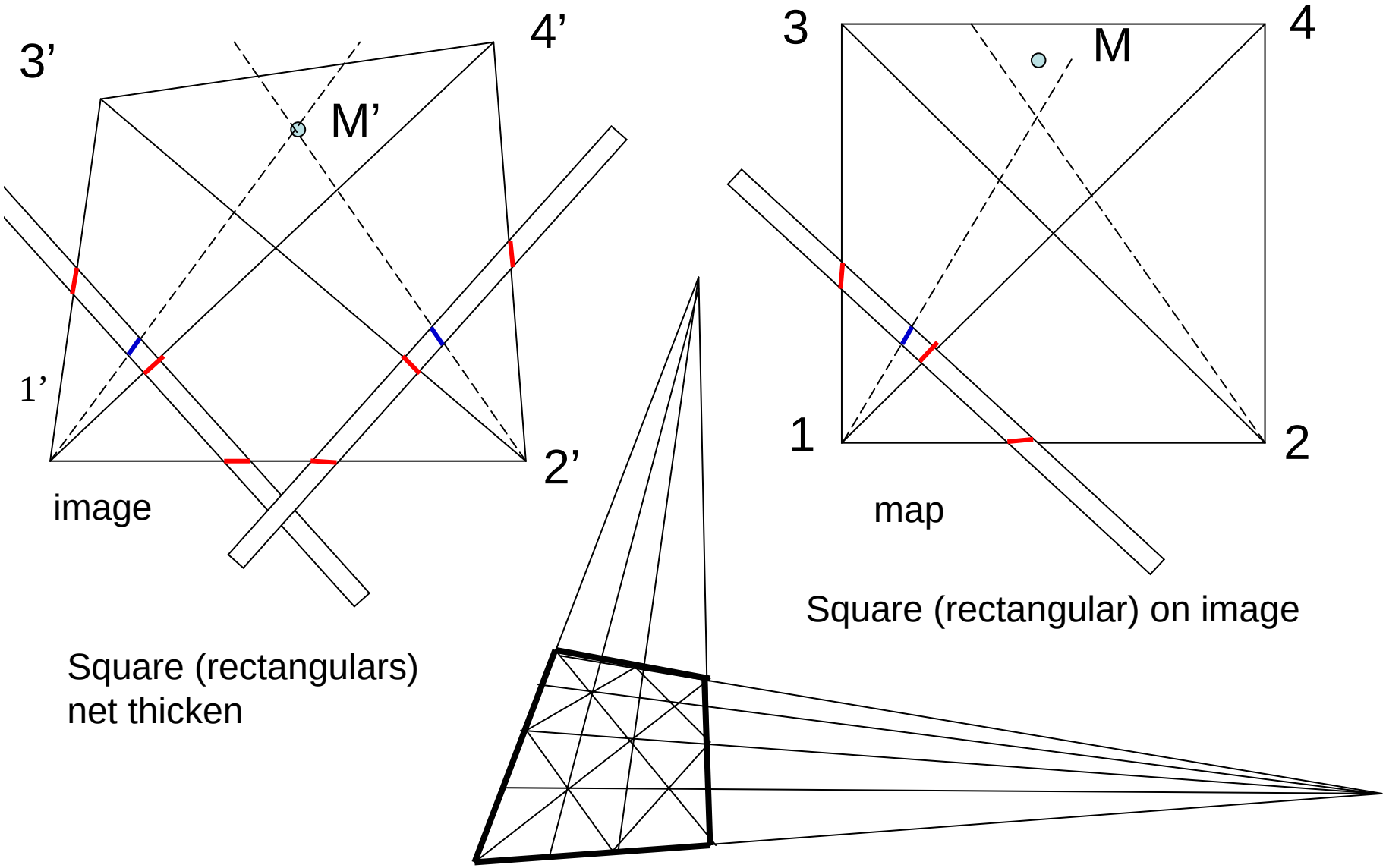
Image transformation (in one image photogrammetry) – chenage of thier geometry basing on projective relationships

Method of image transformation:

1. **Analytical – using analyticla relationships**
2. **Graphical**
3. **Optical – using optical instruments (przetwornik optyczny)**
4. **Photomachanical – using photomechanical instruments**

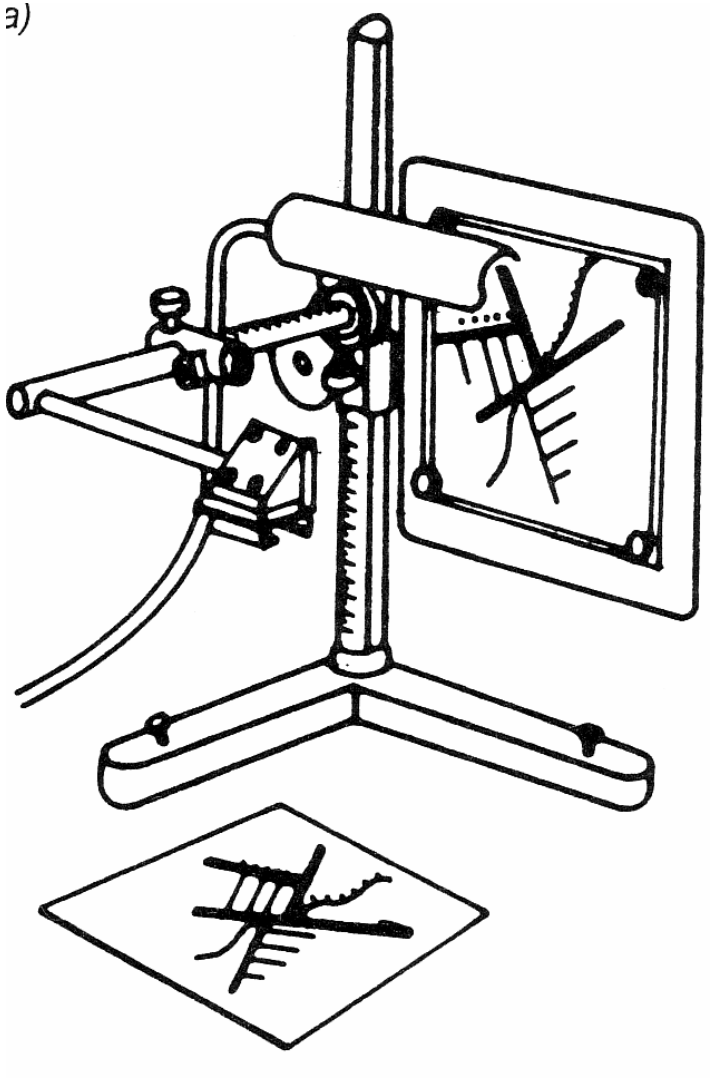
Geometrical method

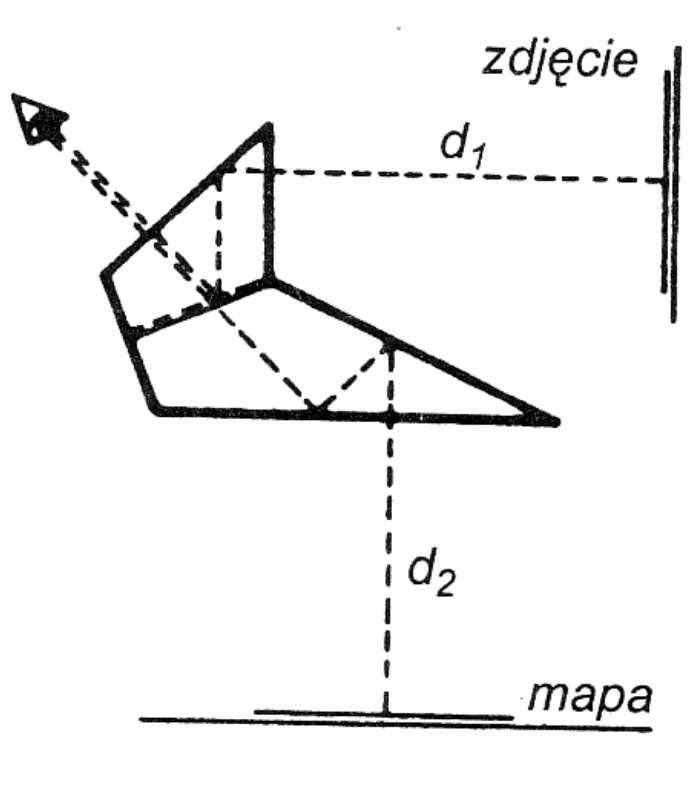
Graphical transformation – paper strip method



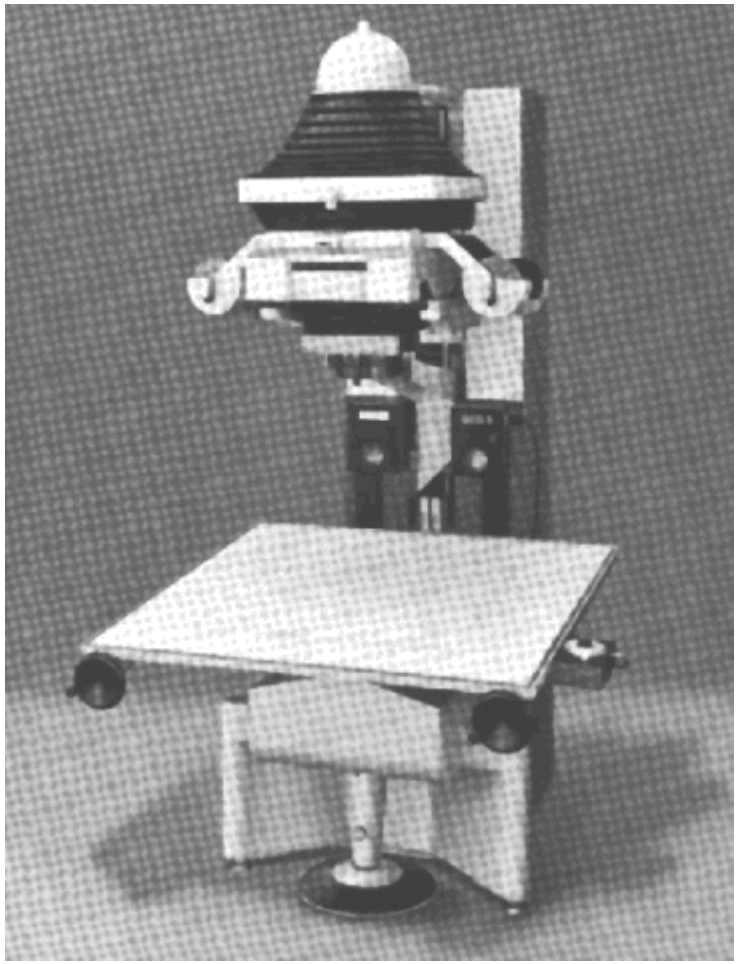
Optical method

Optical instrument LUZ Zeissa

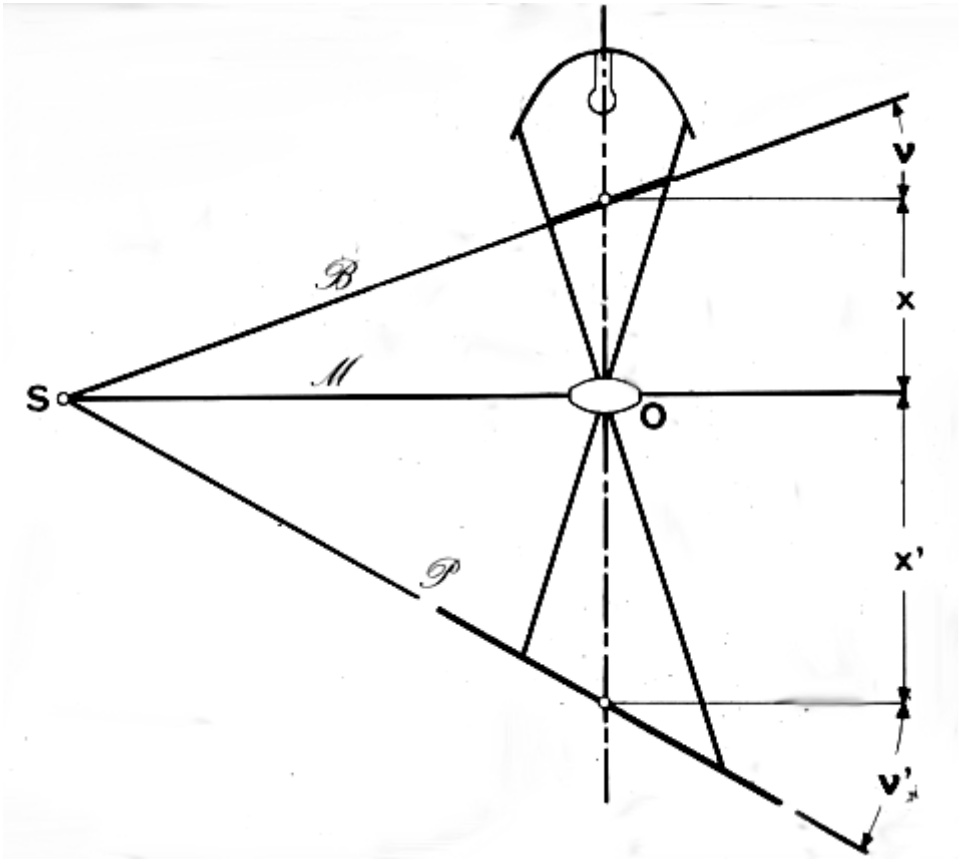




Photomechanical method

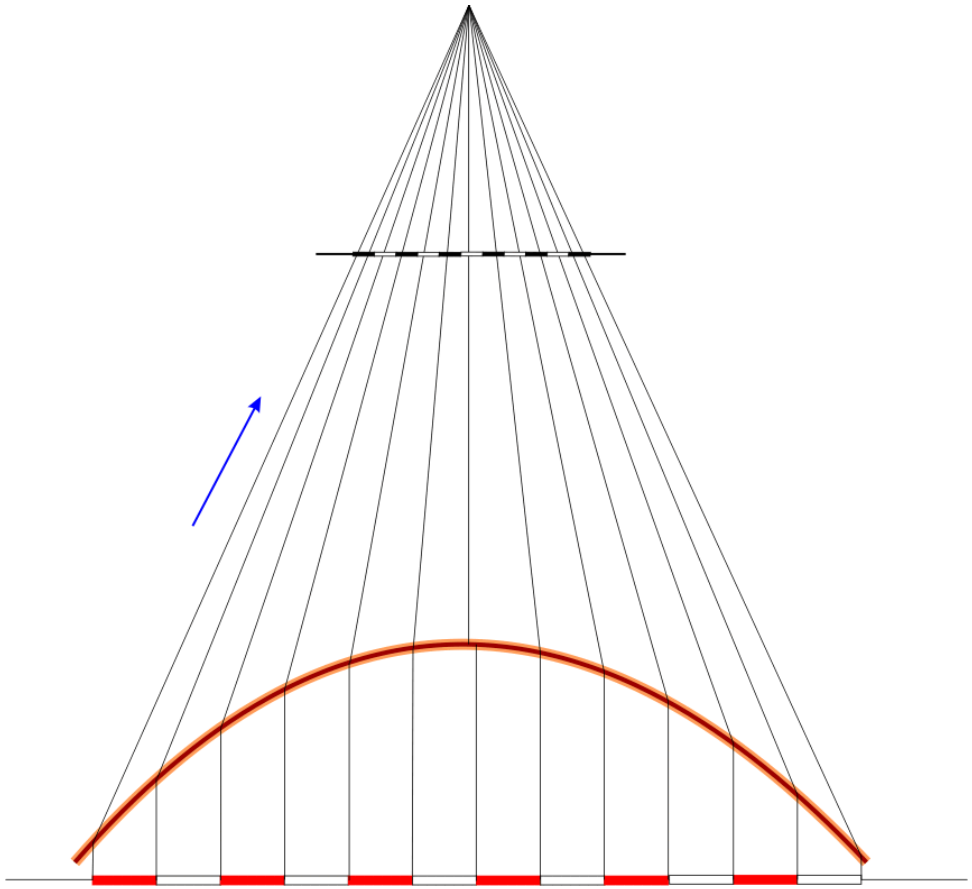


Photomechanical instrument SEG



Czapski-Scheinpflug condition

Orthorectification



Digital image B

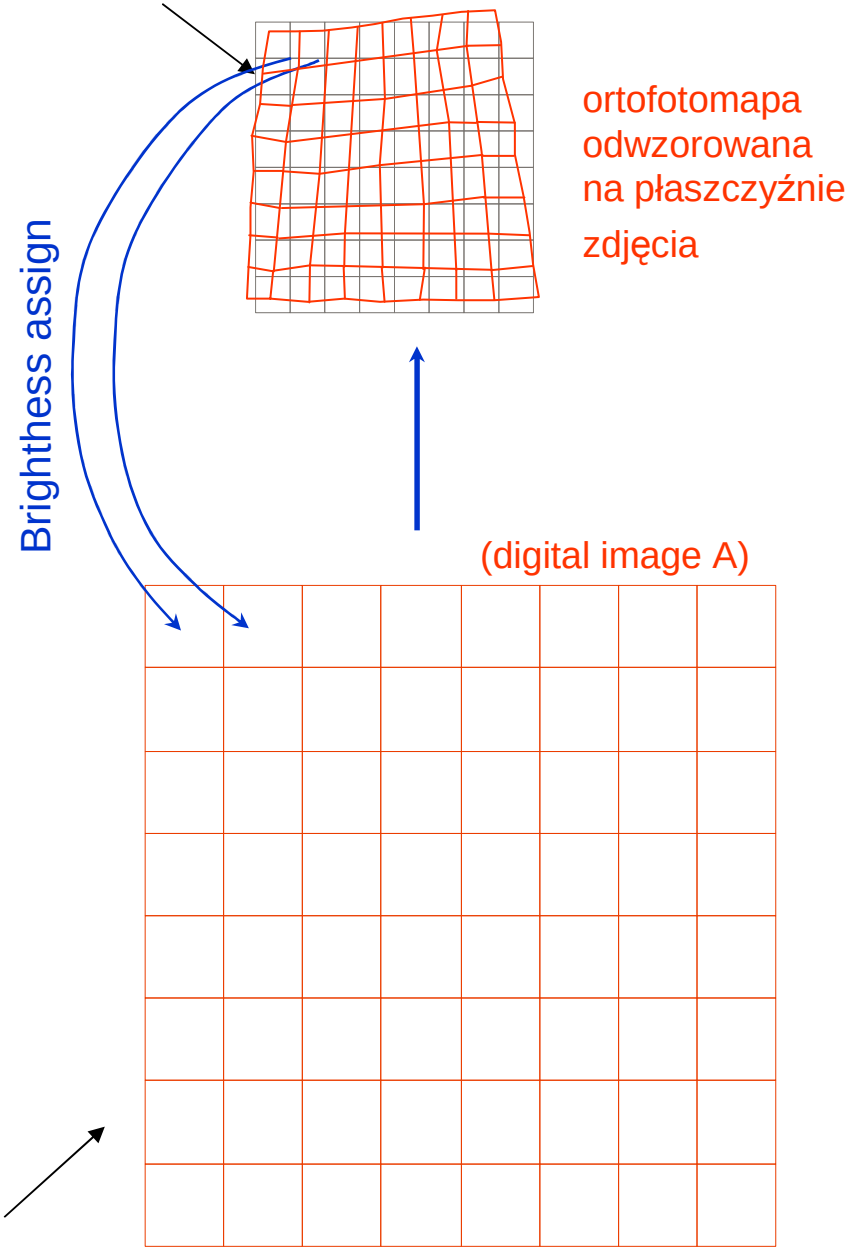
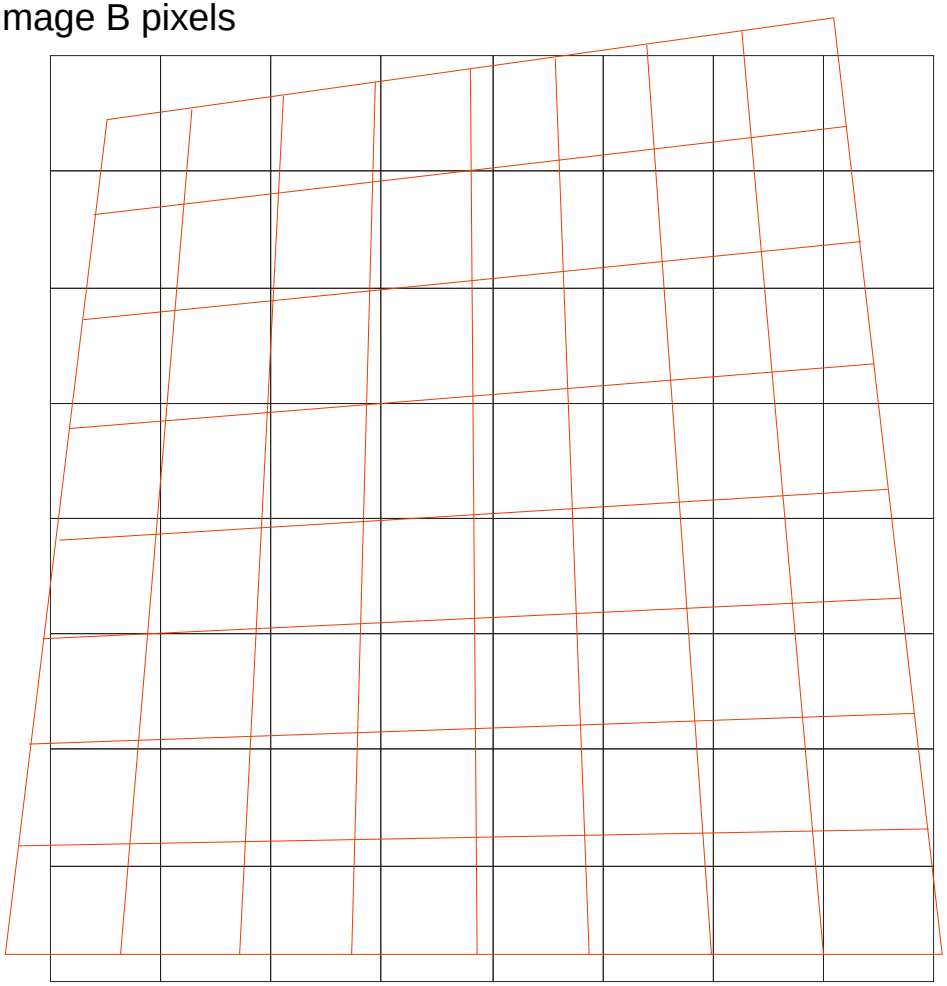


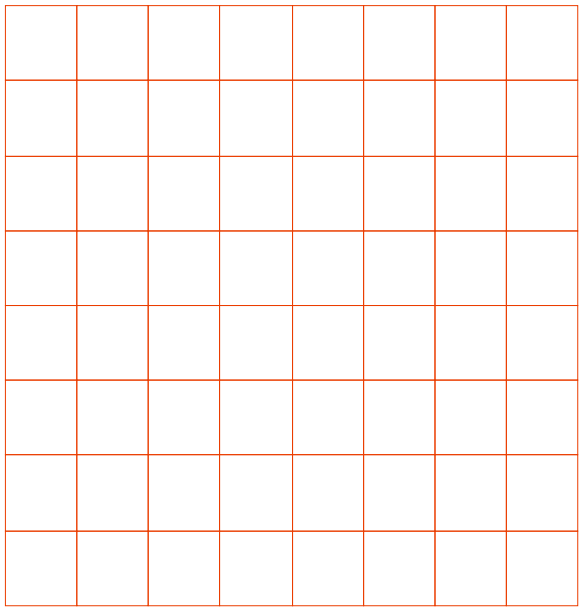
image B pixels



Pixels of image A (photomap/orthophotomap) mapped on the image and their centres

New image (A) generation on the base of brightness of source image B is called resampling

Image A pixels



Ortho generation

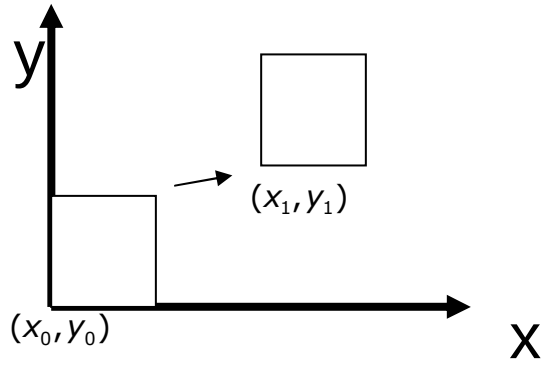
- Change of the image geometry – analytical function
- New image generation - resampling

New image generation

shift

$$x = x_0 + x_1$$

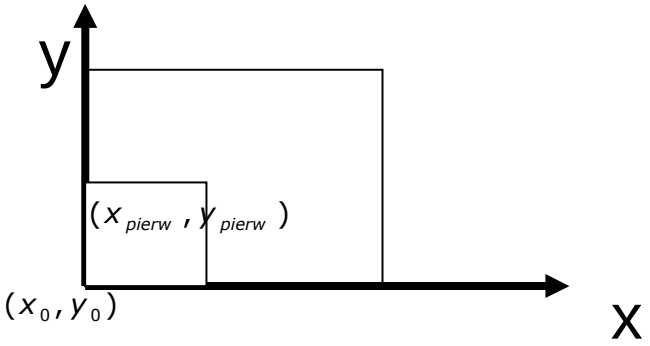
$$y = y_0 + y_1$$



scale

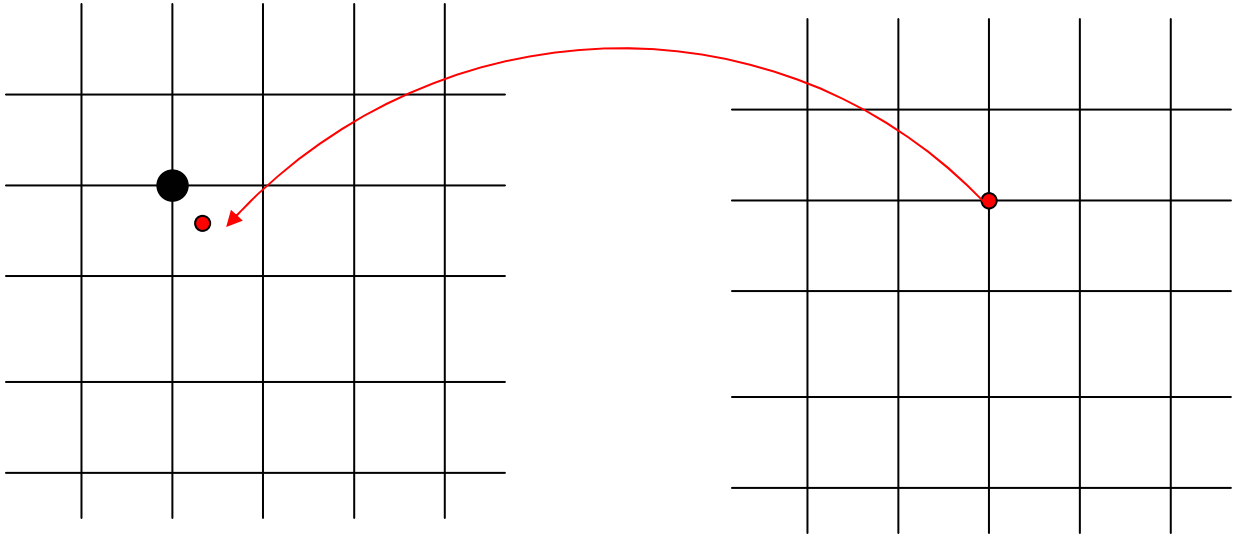
$$x = x_{pierw} \cdot skala$$

$$y = y_{pierw} \cdot skala$$



Reoation, sahpe change etc.

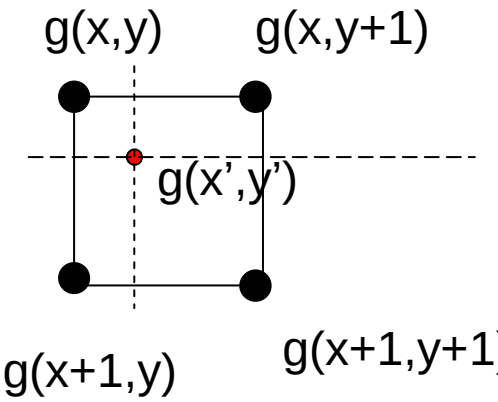
Resampling

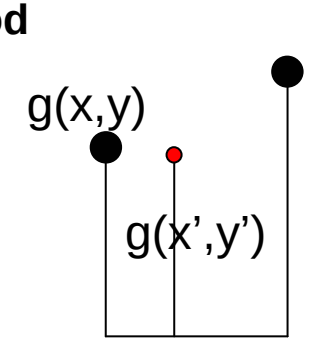


Source image

Target image

1. Near **neighbourhood**

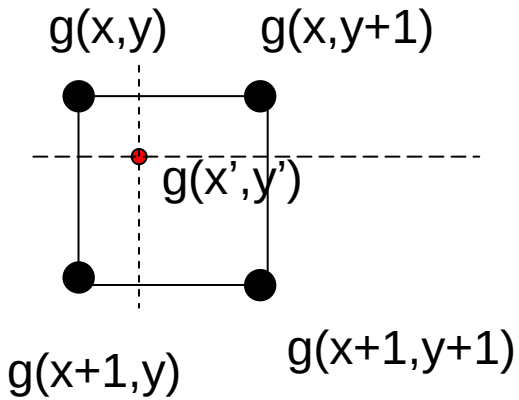




g(x’,y’)= g(x,y)

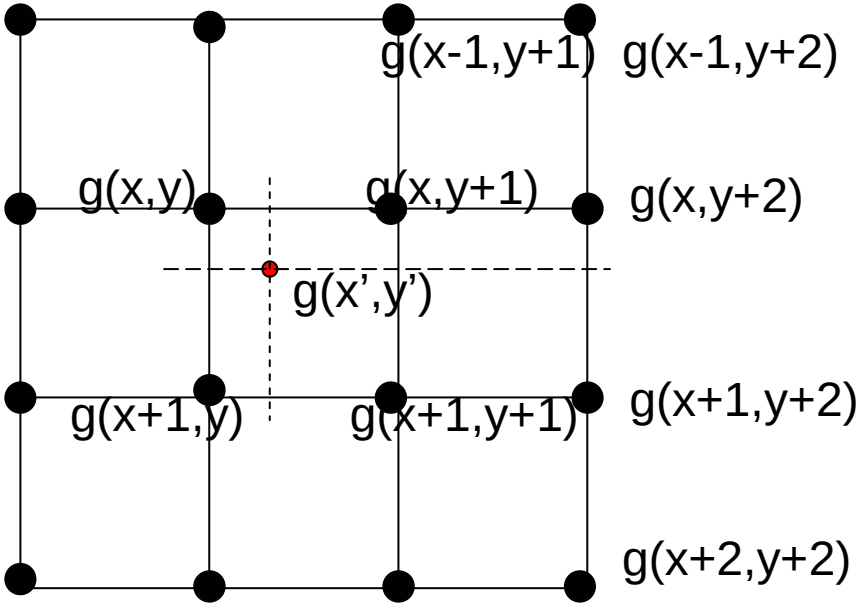
Resampling

2. billinear



g(x’,y’)=f(g(x,y), g(x,y+1), g(x+1,y), g(x+1,y+1))

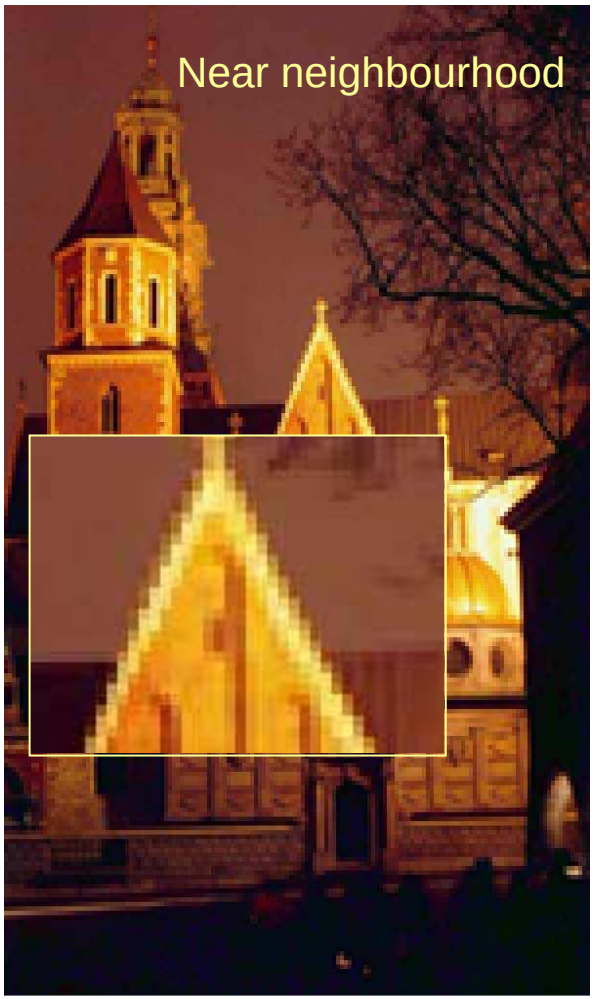
3. Bicubic

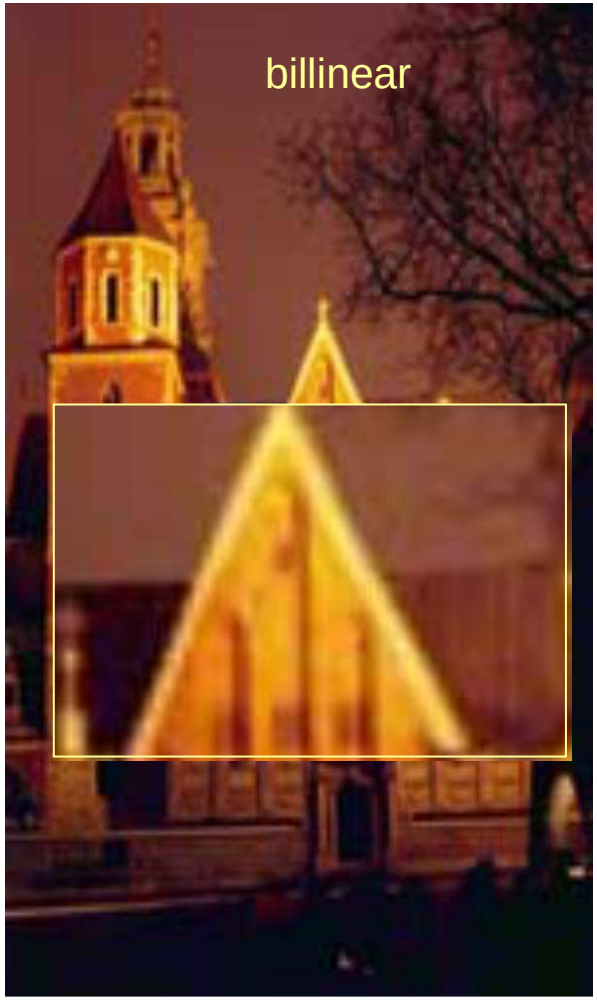


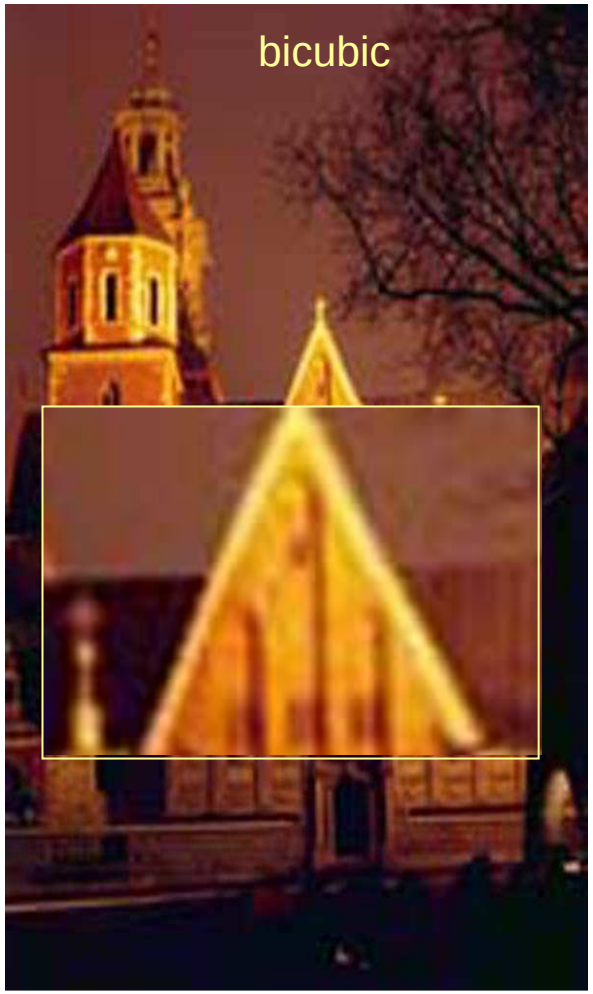
g(x’,y’)=(f(g)16 rouding pixels)

Resampling – different methods

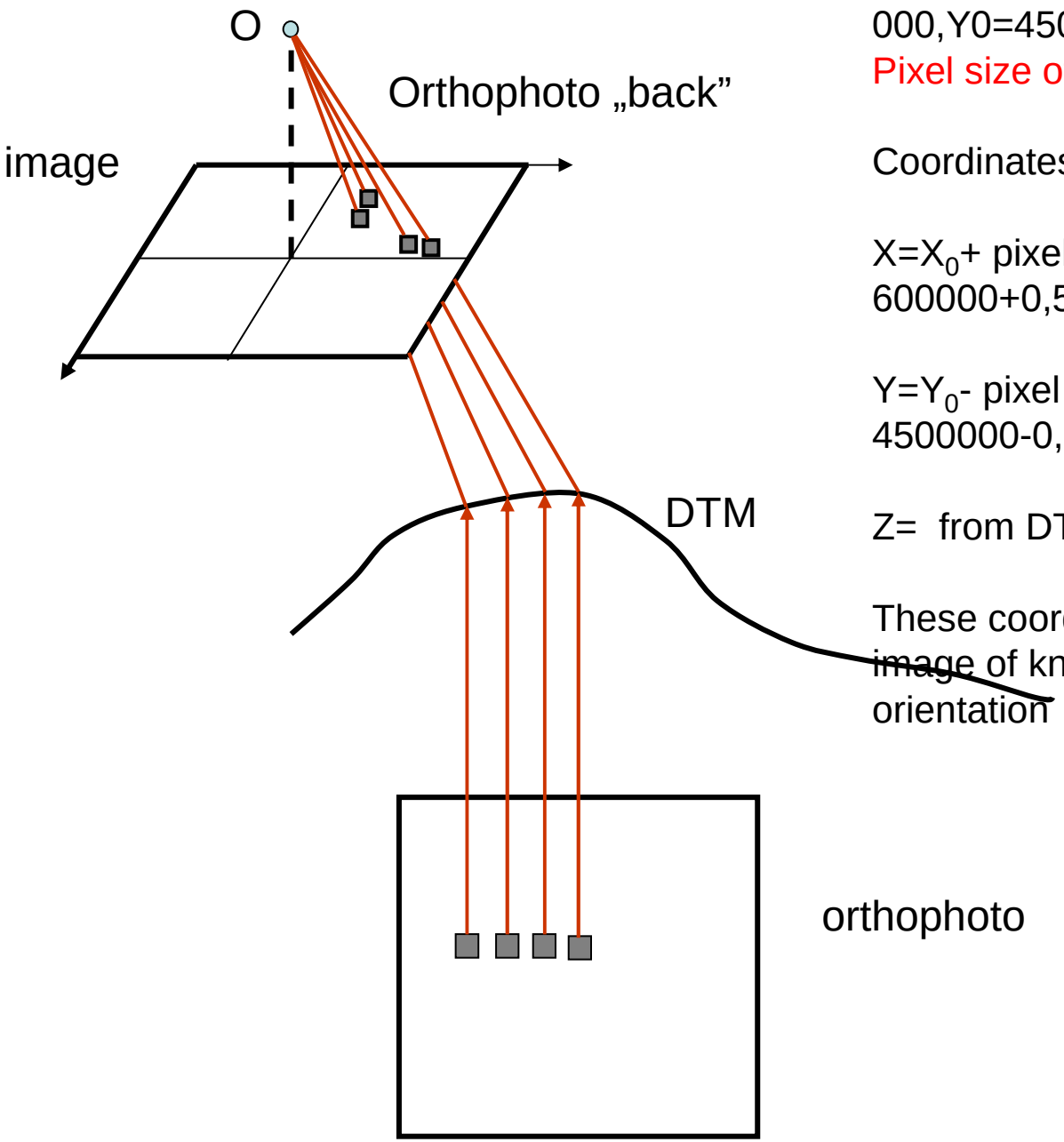
Source image: resoultion 150x221 pixels







Orthophoto



Example:

Coordinates of UL ortho : X0=600 000,Y0=4500 000

Pixel size of ortho =0,5x0,5 m

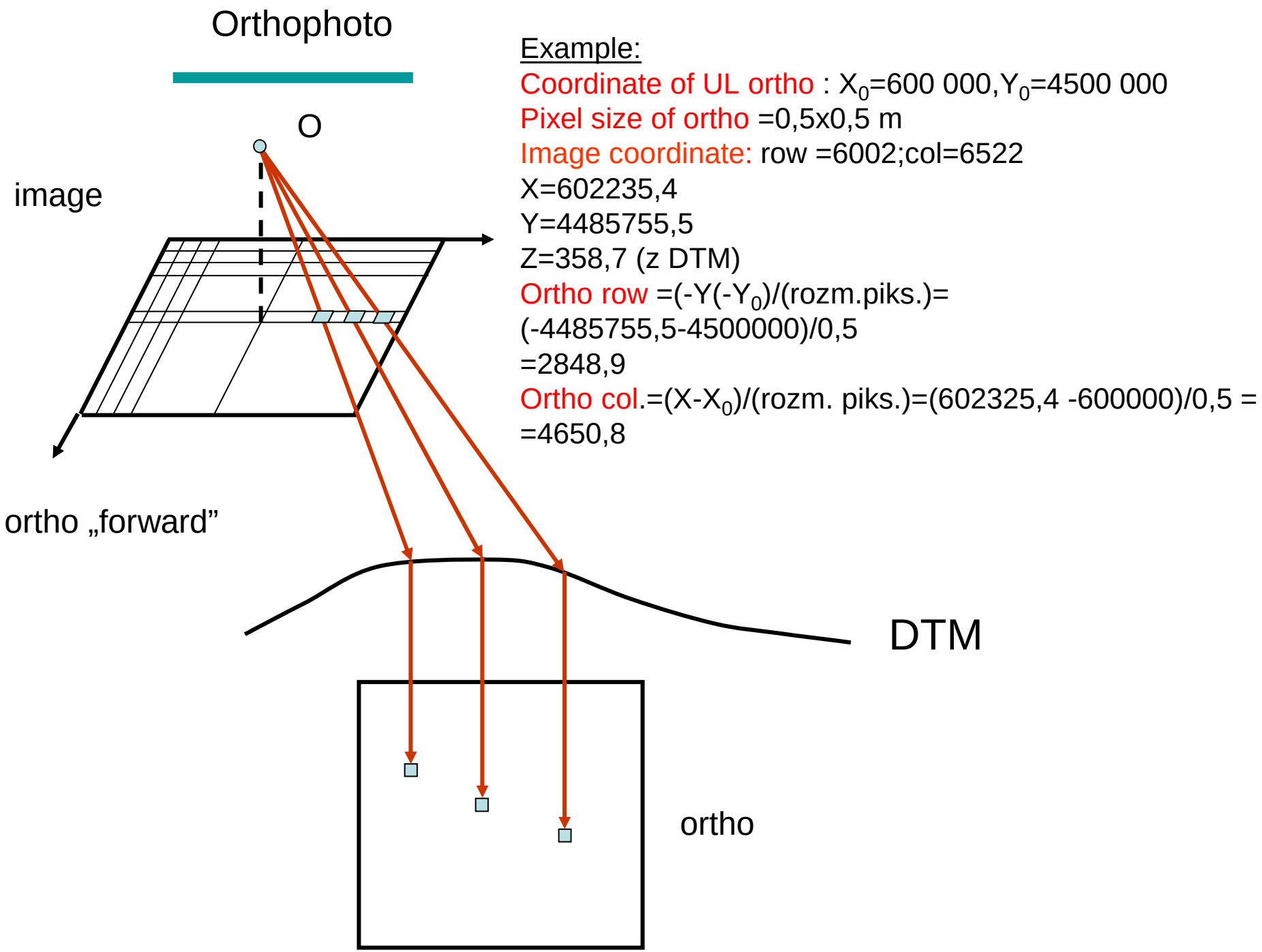
Coordinates on ortho: row=3280, col=700

$X=X_0$+ pixel size x col = 600000+0,5 x 700=600350

$Y=Y_0$- pixel size x row= 4500000-0,5 x 3820=4498090

Z= from DTM = 394 m

These coordinates are projected on the image of known elements of external image orientation



Example:

Coordinate of UL ortho : X_0=600 000,Y_0=4500 000

Pixel size of ortho =0,5x0,5 m

Image coordinate: row =6002;col=6522

X=602235,4

Y=4485755,5

Z=358,7 (z DTM)

Ortho row =(-Y(-Y_0)/(rozm.piks.)=

(-4485755,5-4500000)/0,5

=2848,9

Ortho col.=(X-X_0)/(rozm. piks.)=(602325,4 -600000)/0,5 =

=4650,8

Data needed for image rectification

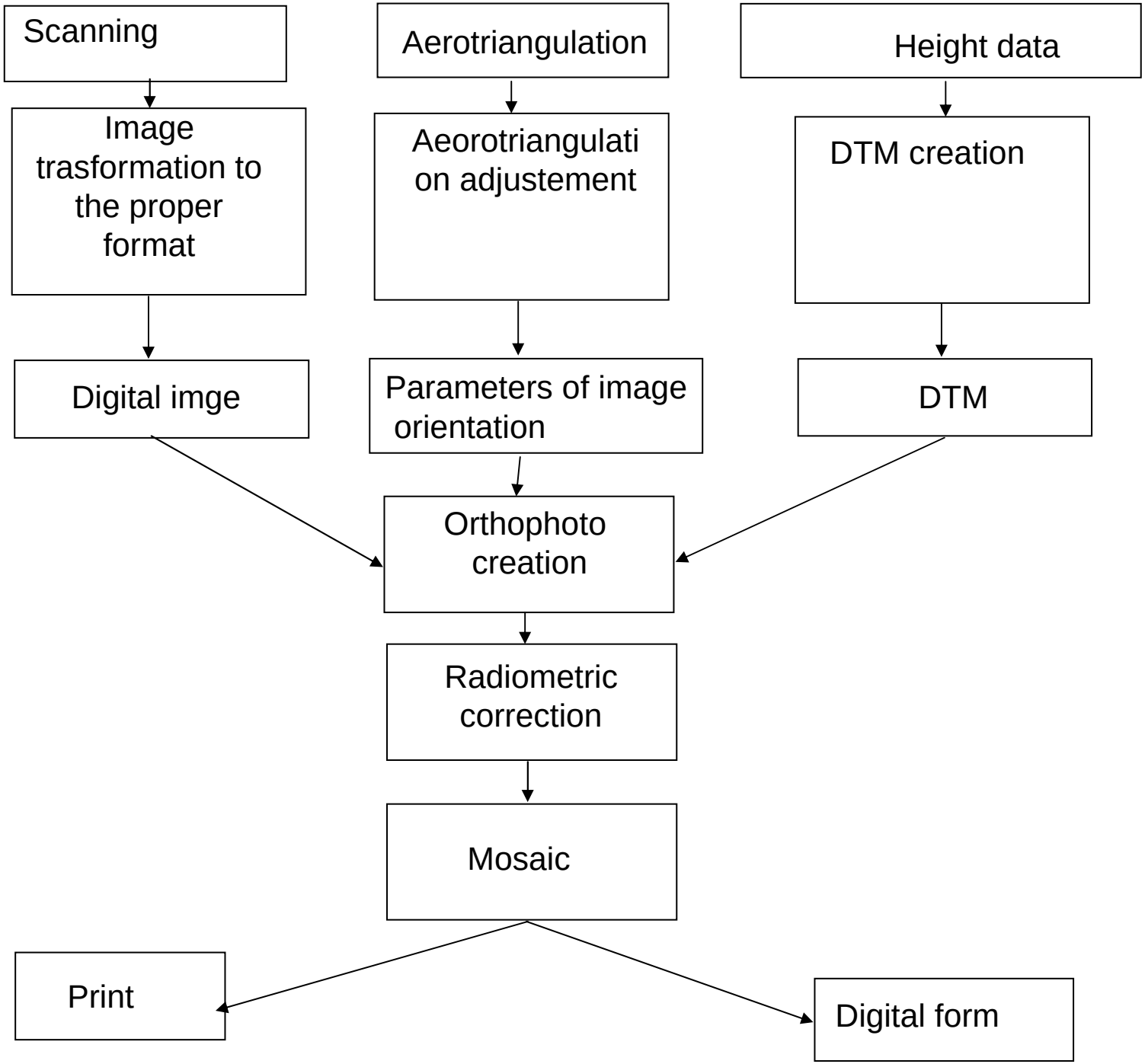
Photomap - 4 points of known x,y,X,Y

Orthophotomap:

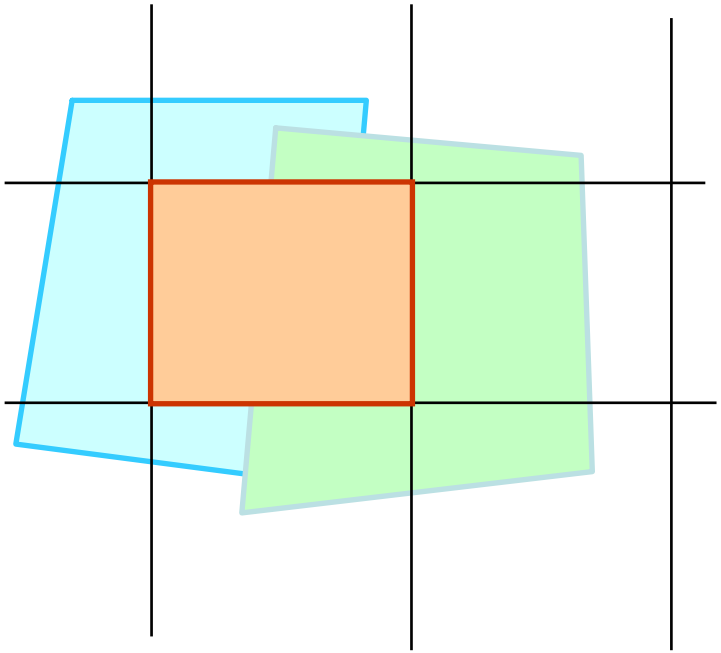
- camera calibration certification (for performing the interior orientation)
- elements of external image orientation (or generation of the elements of external image orientation on teh base of minimum 3 points of known x,y,X,Y,Z)
- Digital Terrain Model

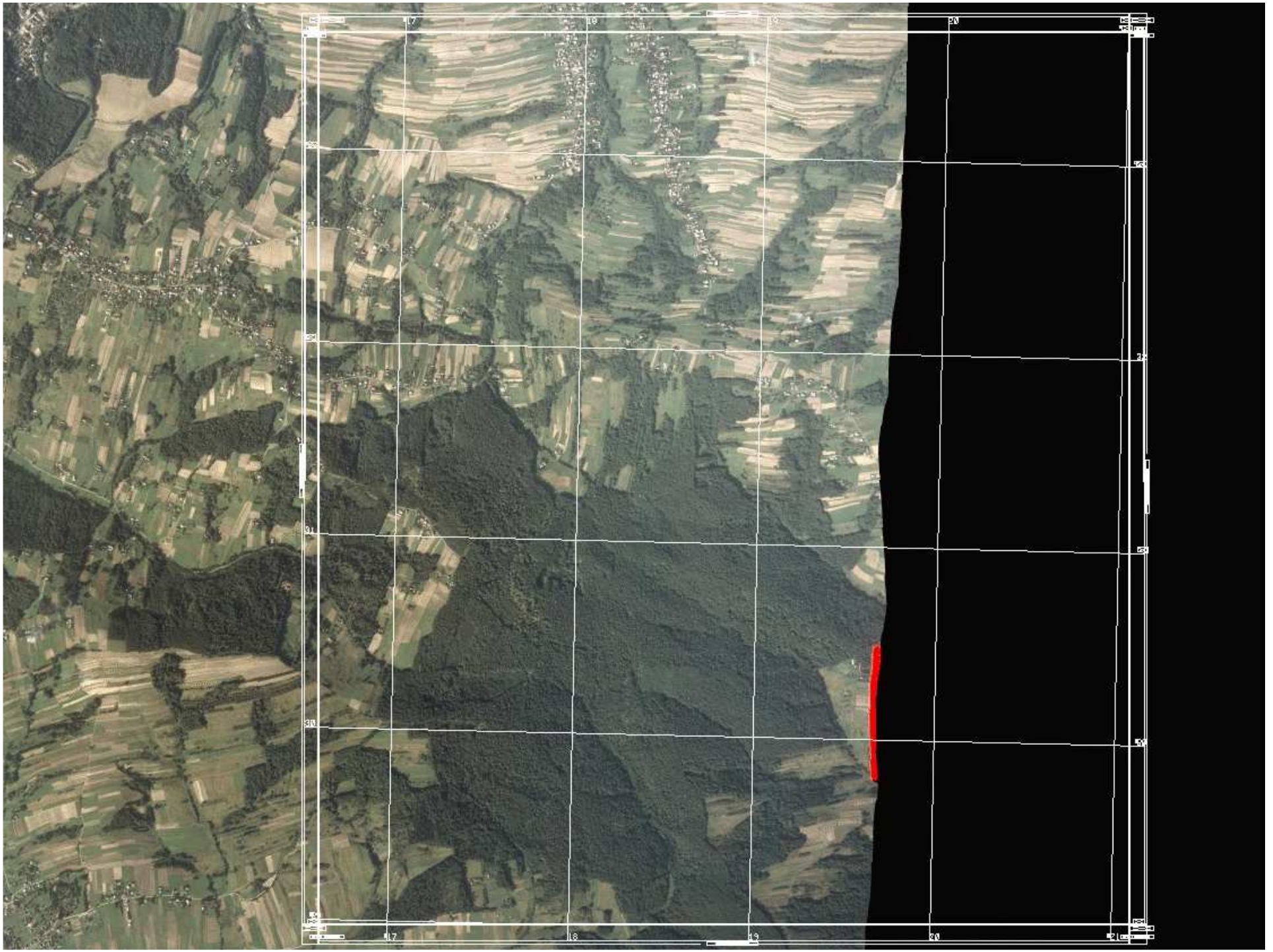
Data can be obtained from:

- aerotriangulation adjustements (will be lectured later)
- measurements of the points on the image and in situ

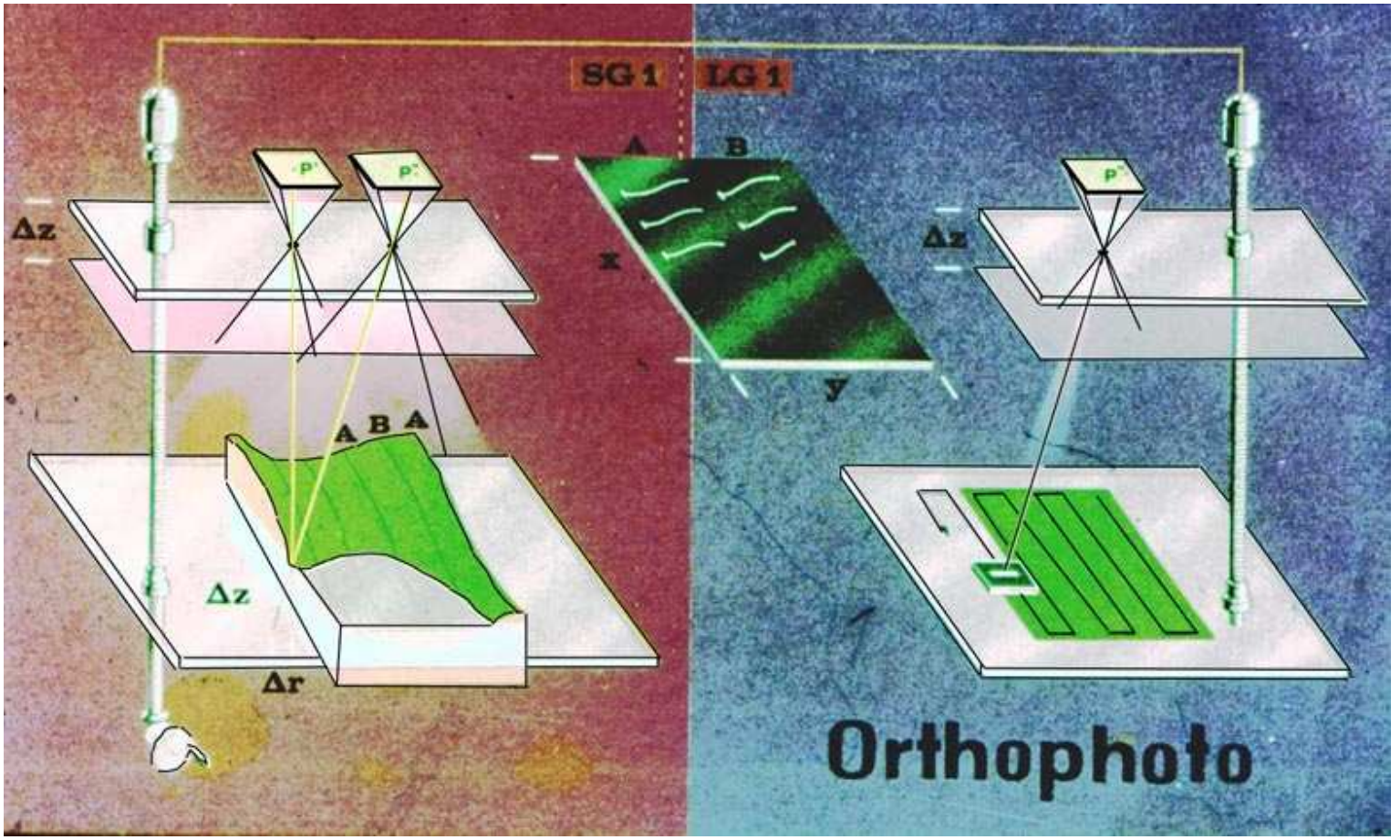

Scanning
Aerotriangulation
Height data
Image trasformation to the proper format
Aeorotriangulation adjustement
DTM creation
Digital imge
Parameters of image orientation
DTM
Orthophoto creation
Radiometric correction
Mosaic
Print
Digital form

Mosaic





Orthophotography

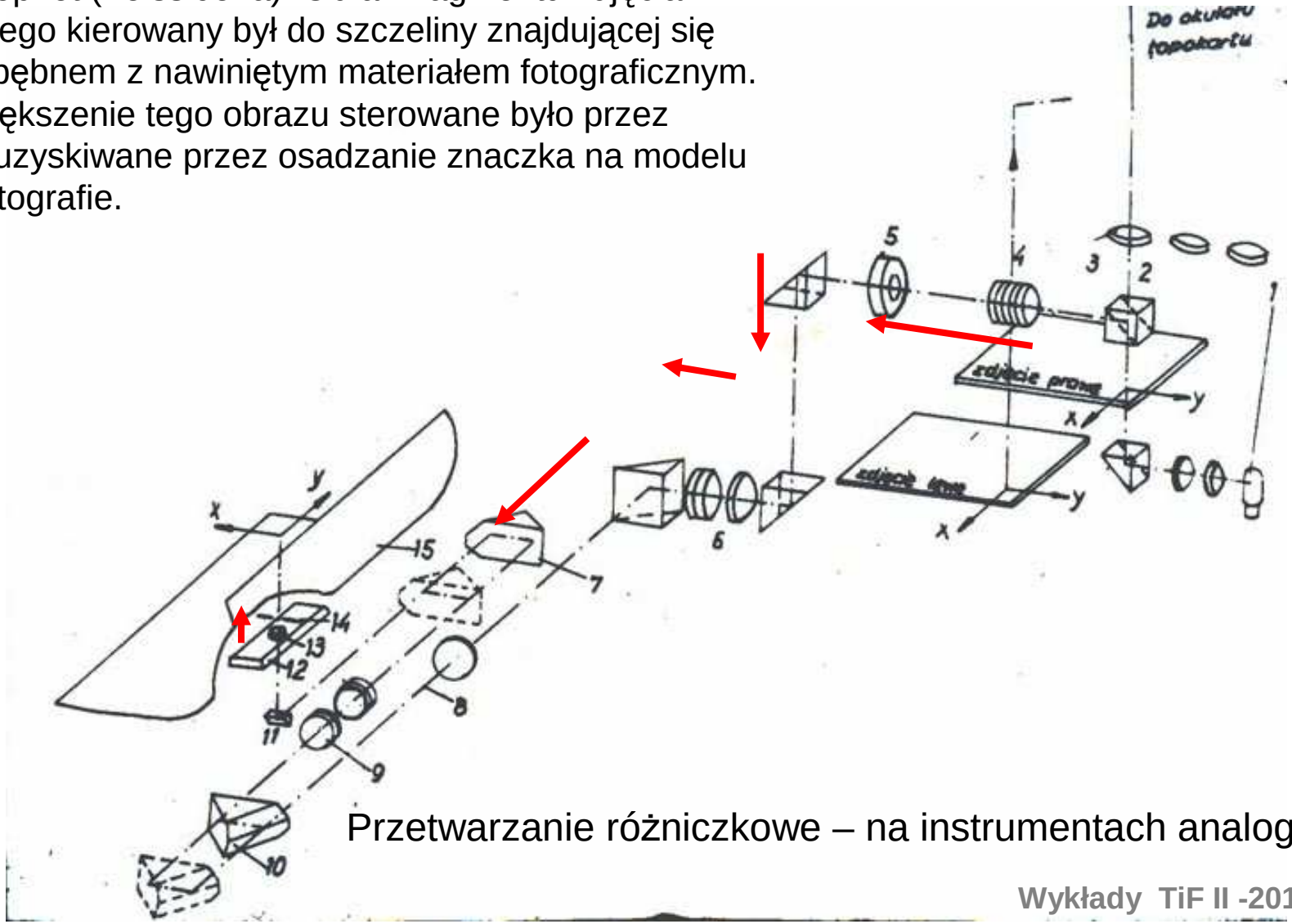


Diffrential transformation (processing) – using analog inftruments

Ortho prjector is composed of the camera with changable distance from the exposed plane. Distance chage is performedaccording the changes of the steropaar pjectors in autograph so the measurements mark conductiong elong profile line tought the DTM surface. Image of variable zoom is projected througt the slot on the photosensitive material.

Ortofotografia

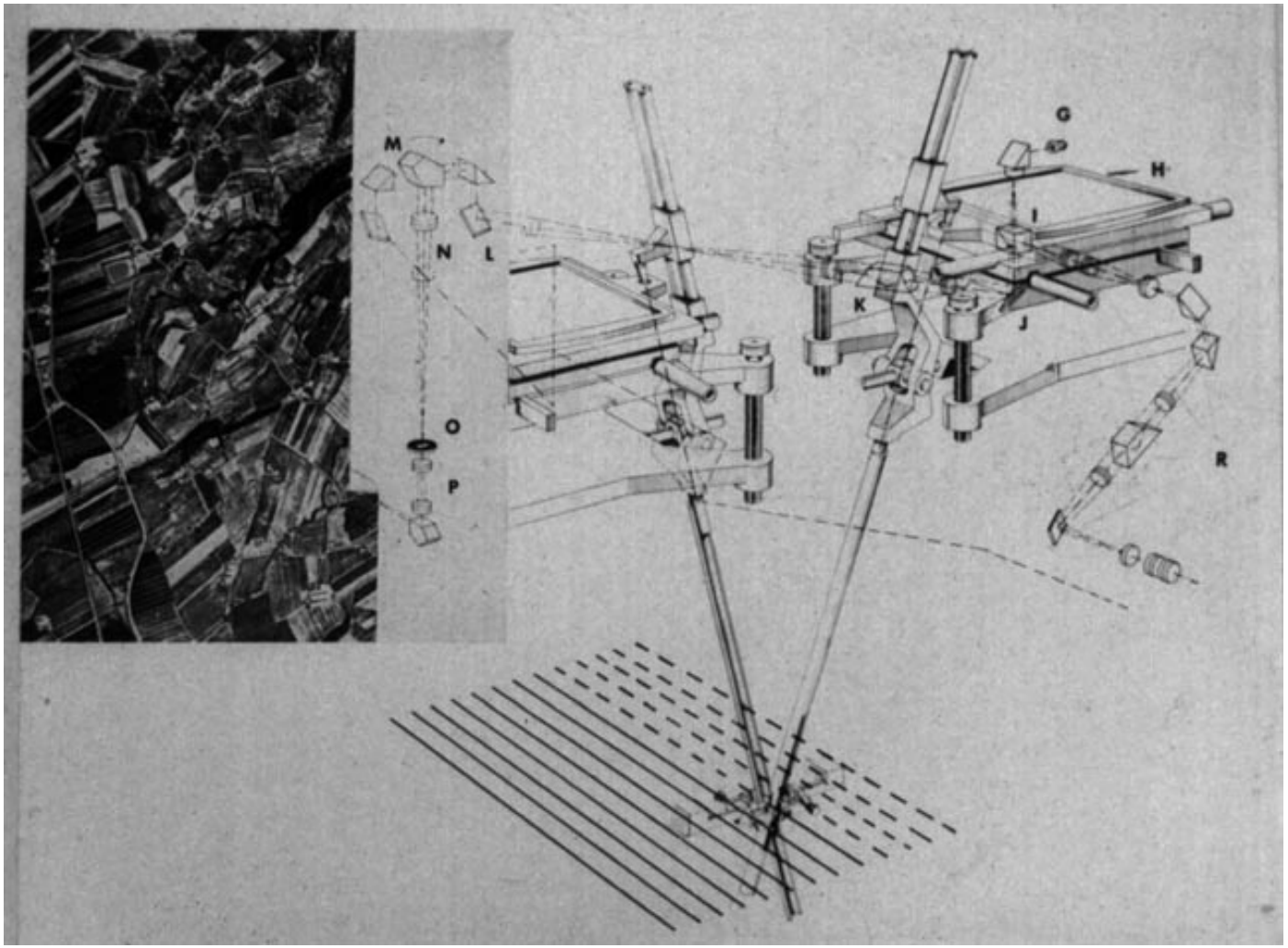
Schemat tworzenia ortofotografii w systemie Topocart- - Ortophot (Zeiss Jena). Obraz fragmentu zdjęcia prawego kierowany był do szczeliny znajdującej się pod bębnem z nawiniętym materiałem fotograficznym. Powiększenie tego obrazu sterowane było przez Z-ty uzyskiwane przez osadzanie znaczka na modelu w autografie.



Przetwarzanie różniczkowe – na instrumentach analogowych

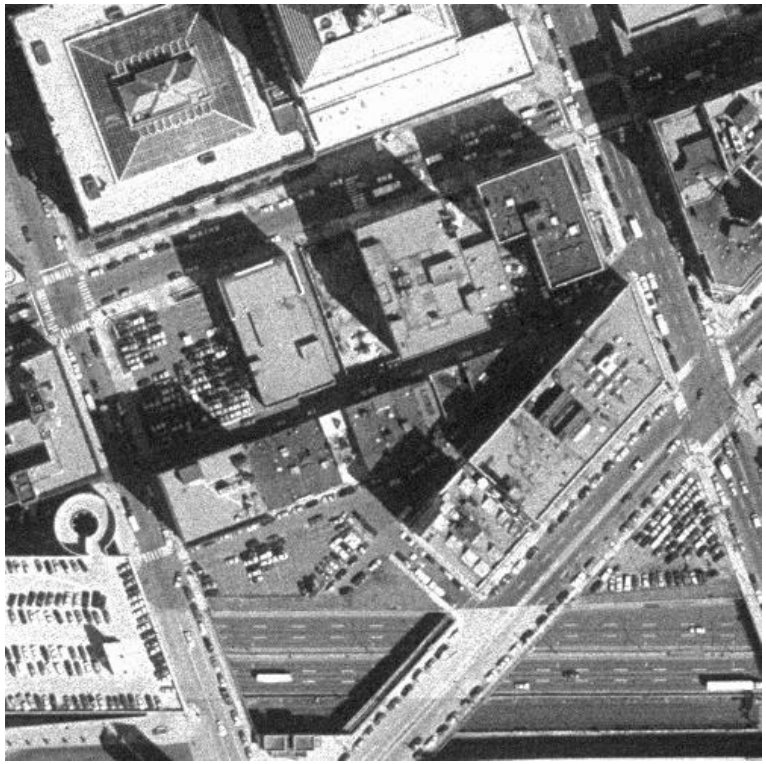
Ortofotografia

Przetwarzanie różniczkowe – na instrumentach analogowych



Schemat tworzenia obrazu w przystawce ortofotoskopowej PPO-8 Wilda

Are there elements on orthophoto presented not properly ?



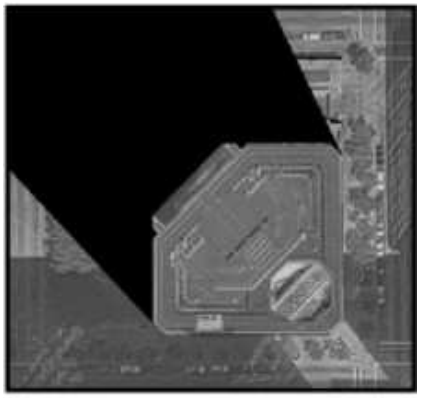
a)

b)

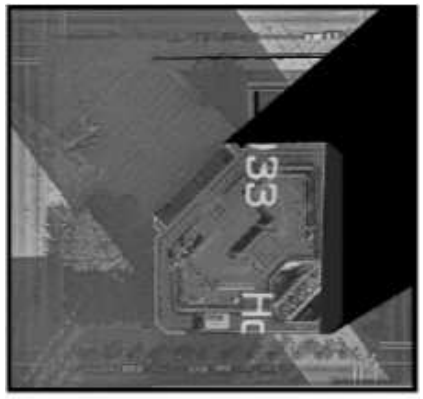
a) near the image centre, b) far away from the image centre

True Ortho – without deformations

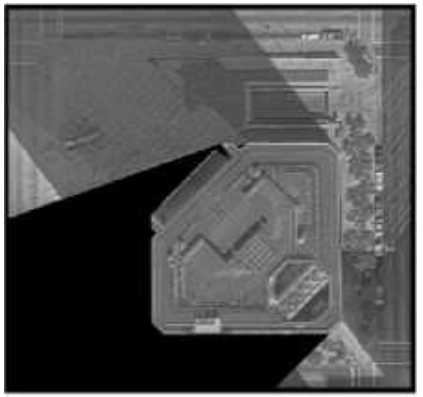
Normal Ortho Mode



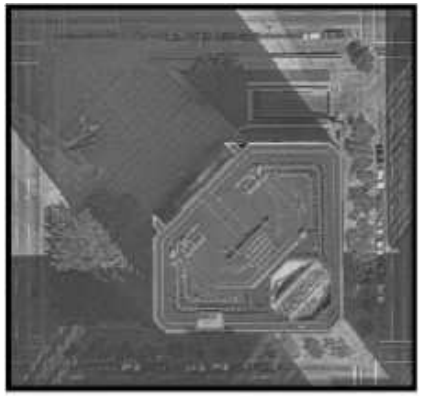
True Ortho Image 1



True Ortho Image 2



True Ortho Image 3



True Ortho Mosaic: Images 1, 2 and 3

Requirements for ortho generation
Scannig of analog data

Scanning pixel size determination :

- Image scale,
- Map scale,
- Planned terrain resolution of orthophotomap,

Requirements:
Scanning pixel size" BW: 12-25 μm, RGB: 20-30 μm
Generally pixel size of ortho 10-20% larger then scannig pixel size.
Resolution of scanning should not be smaller then:

$$RS \geq 320dpi \frac{M_{zdj}}{M_{orto}}$$

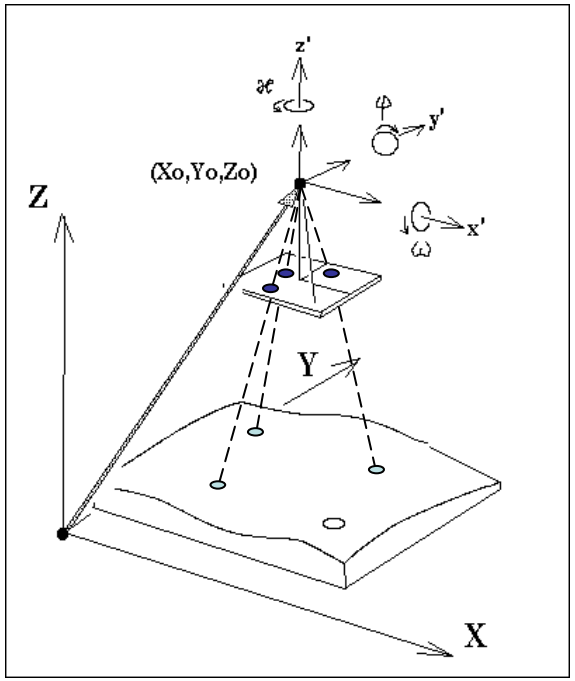
Some exception: moutain area - pixel size can/shoud be smaller

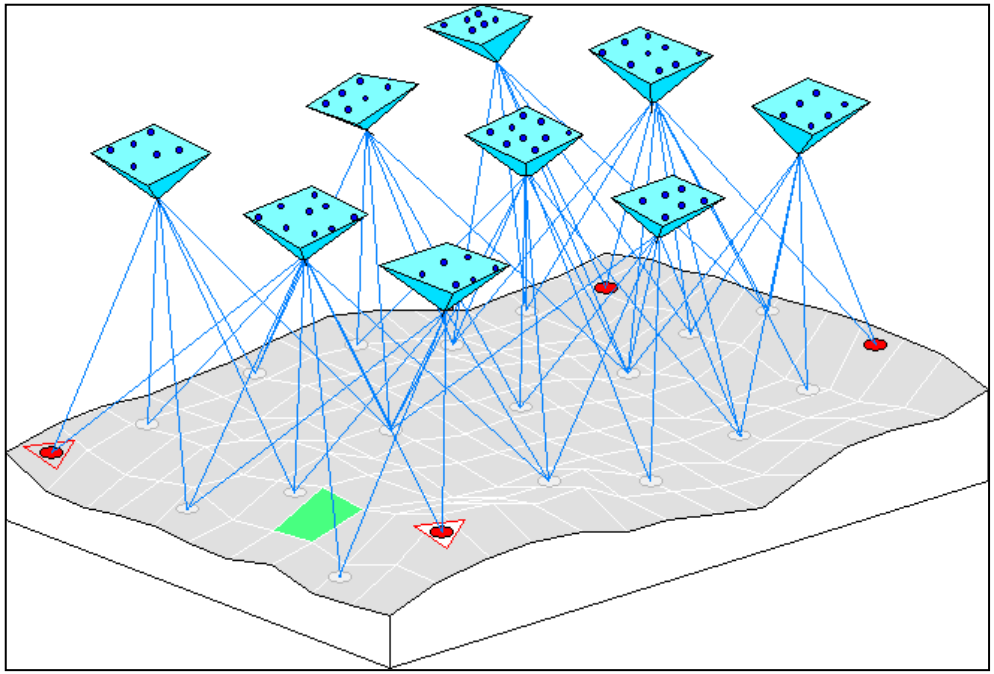
Requirements for ortho generation

Elements of external image orientation

Two possibilities:

- For each iamge separatelly – back calculation form collineaarity equation
- Fro aerotriangulation





Requirements for ortho generation
DTM generation

Maximum value of the accepted height errors of any DTM point for ortho creation process (Wytyczne Techniczne K-2.8 „Zasady Wykonywania Ortofotomap w skali 1:10000” 2001)

Maksymalne błędy wysokości Dla pikseli oddalonych od środka zdjęcia o podaną wielkość	Skala Ortofotomapy					
	1:2000		1:5000		1:10000	
	Stała kamery c_k [mm]					
	150	300	150	300	150	300
R = 3,5 cm	2,4 m	4,8 m	6,0 m	12,0 m	12,0 m	24,0 m
R = 7,0 cm	1,2 m	2,4 m	3,0 m	6,0 m	6,0 m	12,0 m
R = 14 cm	0,6 m	1,2 m	1,5 m	3,0 m	3,0 m	6,0 m

Requirements for ortho generation
DTM generation

Zalecany interwał siatki (Wytyczne Techniczne K-2.8 „Zasady Wykonywania Ortofotomap w skali 1:10000” 2001)

Stopień trudności terenu	Skala opracowywanej ortofotomapy		
	1:2000	1:5000	1:10000
	Mianownik skali zdjęć		
	5000-8000	12000-18000	20000-30000
Łatwy	10-15 m	15-20 m	20-30 m
Trudny	5-10 m	10-15 m	15-20 m

Requirements for ortho generation

Ortho pixel size determiantion

Terenowe wymiary piksela ortoobrazu (Wytyczne Techniczne K-2.8 „Zasady Wykonywania Ortofotomap w skali 1:10000” 2001)

Rodzaj zdjęć	Skala Ortofotomapy			Uzyskana rozdzielczość ortofotomapy
	1:2000	1:5000	1:10000	
	K=4	K=3,5	K=3	
Czarno-białe	16 cm	40 cm	80 cm	317 dpi
Barwne	20 cm	50 cm	100 cm	254 dpi

$$K = \frac{M_{zdj}}{M_{orto}}$$

Requirements for ortho generation

Accuracy requirements

Maksymalne błędy położenia (przesunięcia radialne) w mm na ortofotomapie w funkcji błędu wysokości określonej z NMT w miejscu odpowiadającym narożnikowi zdjęcia. Dane z tabeli można wykorzystać do obliczenia błędów w odległości R od punktu głównego zdjęcia, poprzez pomnożenie przez współczynnik R/140. (Wytyczne Techniczne K-2.8 „Zasady Wykonywania Ortofotomap w skali 1:10000” 2001)

Błąd określenia wysokości DZ [m]	Skala ortofotomapy					
	1:2000		1:5000		1:10000	
	Stała kamery c_k [mm]					
	150	300	150	300	150	300
0,5	0,2	0,1	0,1	0,0	0,0	0,0
1,0	0,5	0,2	0,2	0,1	0,1	0,0
2,0	0,9	0,5	0,4	0,2	0,2	0,1
3,0	1,4	0,7	0,6	0,3	0,3	0,1
5,0	2,3	1,2	0,9	0,5	0,5	0,2
10,0	4,7	2,3	1,9	0,9	0,9	0,5

Requirements for ortho generation

Accuracy requirements

$$M_O = m_{NMT} \cdot \frac{r}{c_k}$$

Ortho accuracy depends on:

- Geometrical scanning accuracy and scanning pixel size
- Accuracy and density of DTM
- Camera constanto
- Accuracy of elements of external image orientation (i.e. Aerotriangulation)
- Algorythm of ortho generation
- Terrain spatial resolution of ortho

Requirements for ortho generation

Accuracy requirements

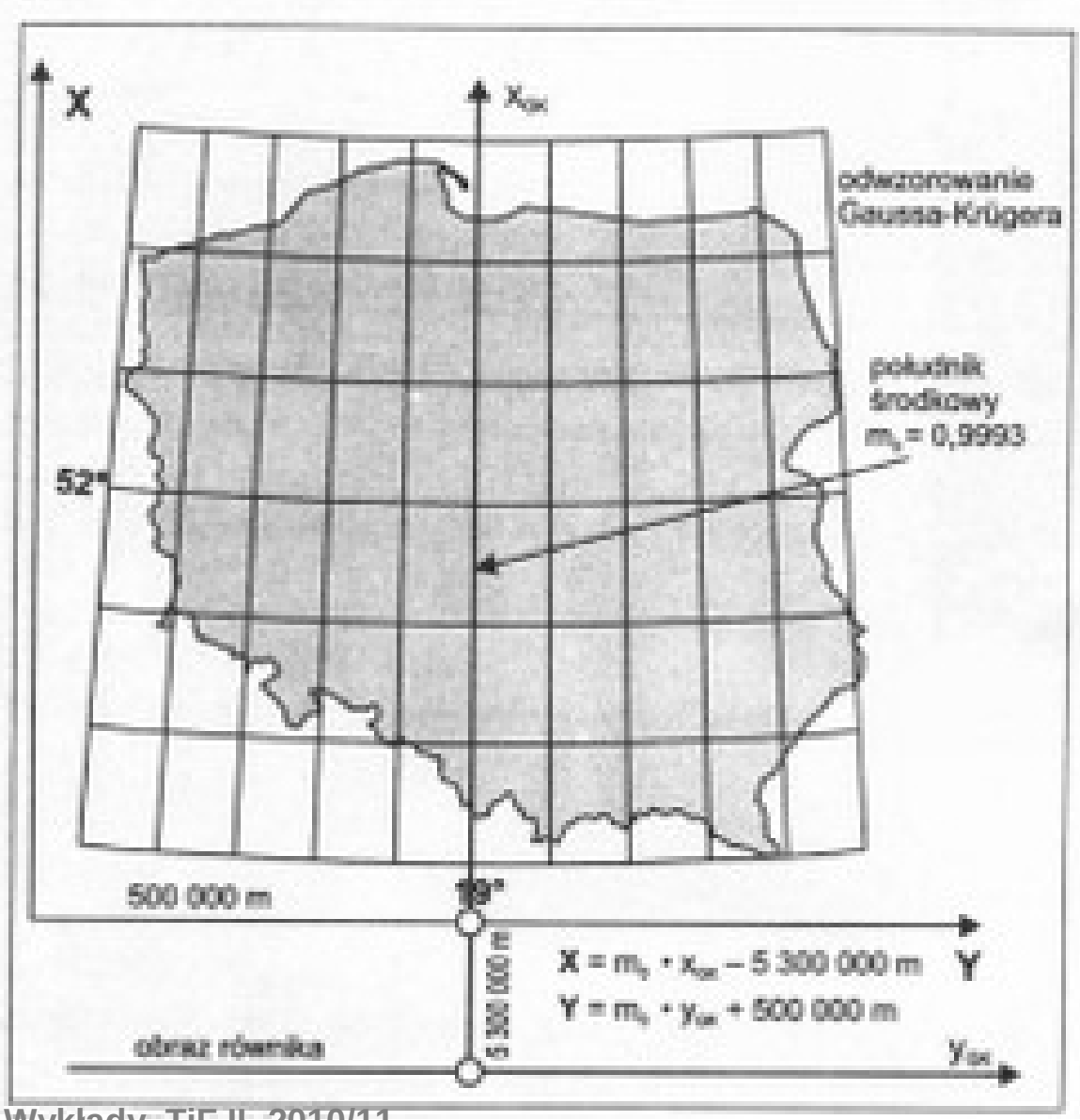
$$m_{orto} = \sqrt{\frac{[\varepsilon\varepsilon]}{n}}$$

Error is calulated on the base on discrepancies between control points measured in the field and on the ortho

Średnie błędy położenia szczegółów na ortofotomapie (Wytyczne Techniczne K-2.8 „Zasady Wykonywania Ortofotomap w skali 1:10000” 2001)

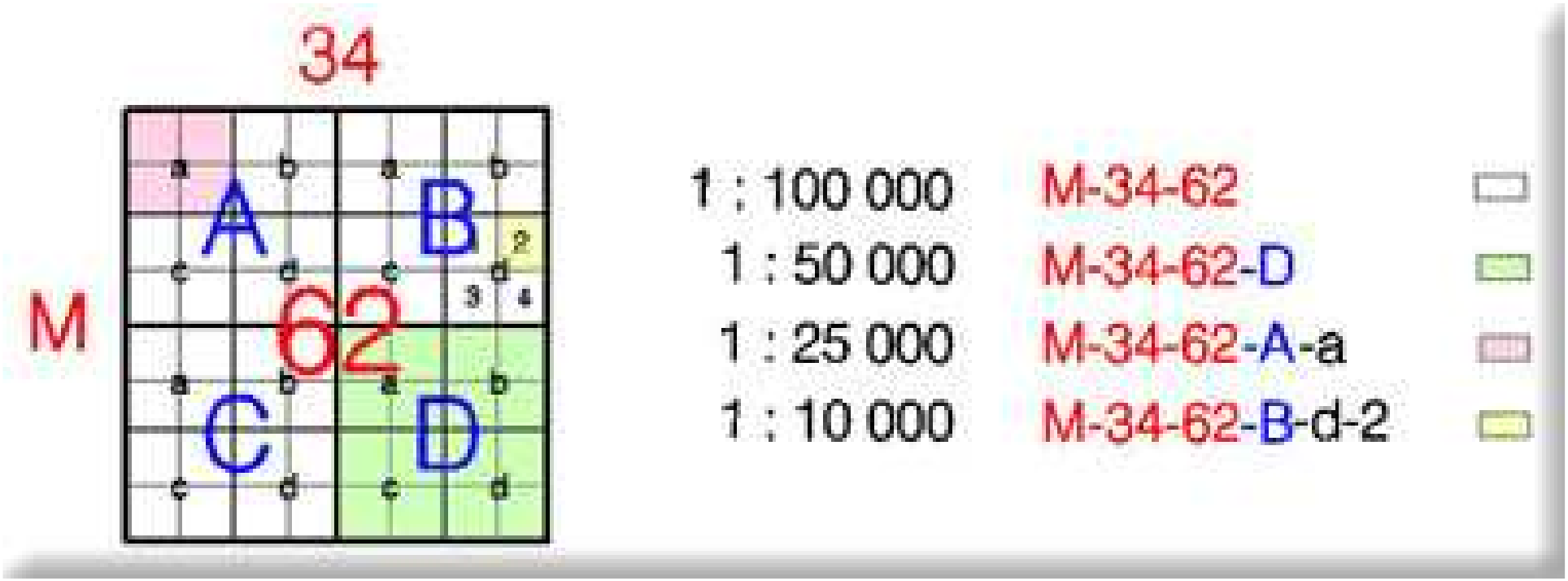
Średnie błędy położenia	Skala ortofotomapy		
	1:2000	1:5000	1:10000
Na ortofotomapie	0,3 mm	0,3 mm	0,3 mm
W terenie	0,6 m	1,5 m	3,0 m

Ortho -orthophotomap



Układ 1992

Ortho -orthophotomap



Topographical map sheets 1 :100 000