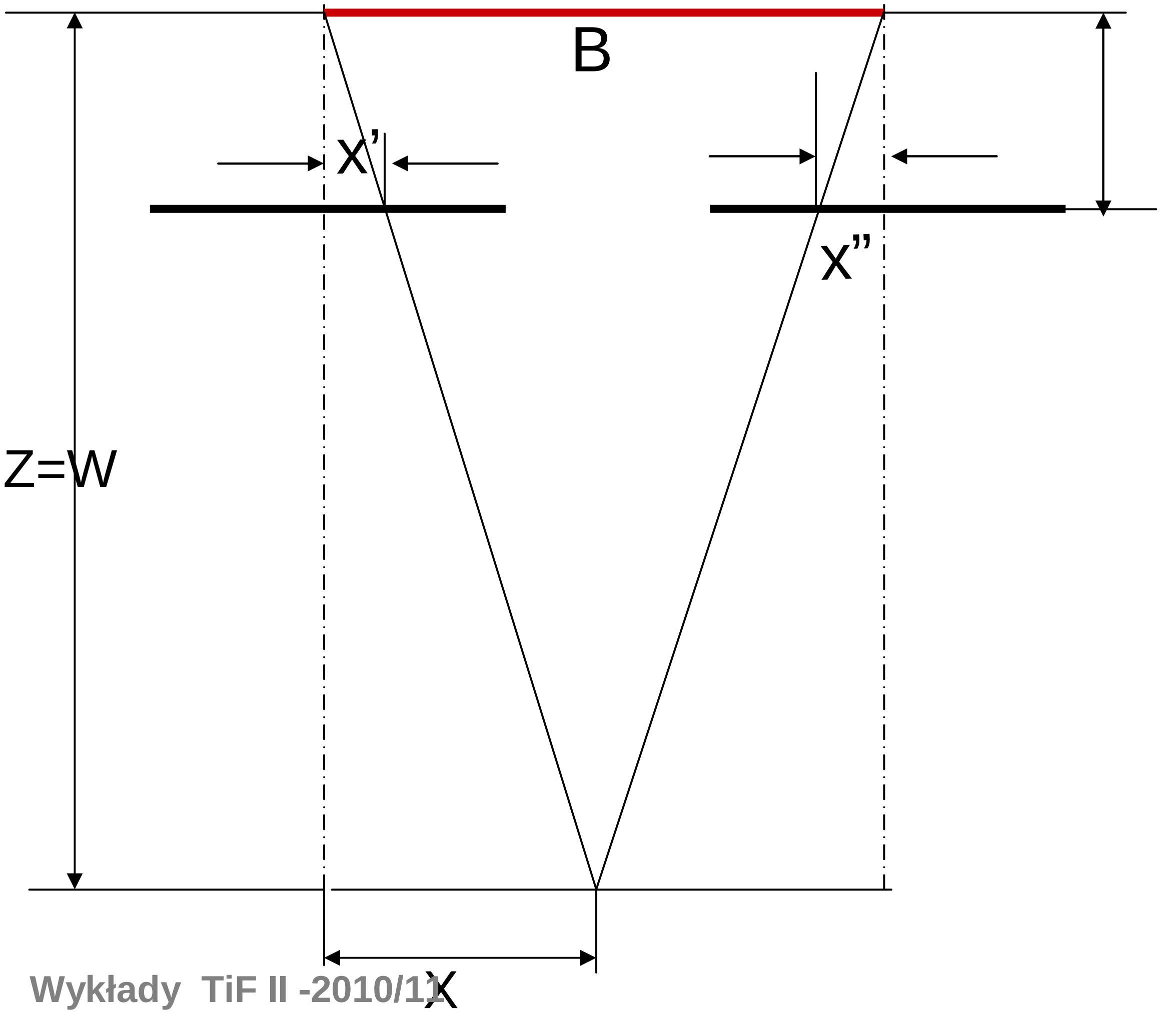
Metods andproducts of airborne image processing

W9

- Analytical model generation form steropair of airborne images using relative and absolute orientation
- Analogue, analytical and digital stereoplotters, stereoplotting.

Regina Tokarczyk

Calculation of spatial coordinates „normal case”



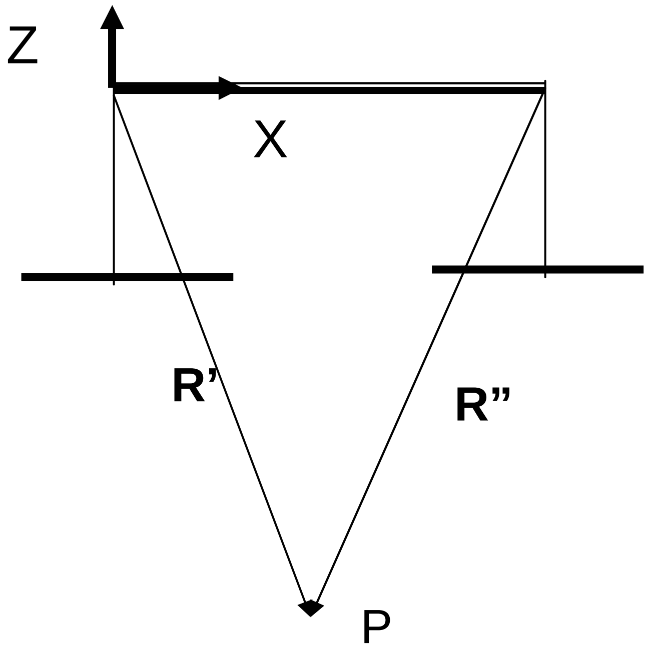
$$Z = W = \frac{B}{p} \cdot c_k$$

$$X = \frac{W}{c_k} \cdot x' = \frac{B}{p} \cdot x'$$

$$\Delta Y = \frac{W}{c_k} \cdot y' = \frac{B}{p} \cdot y'$$

$$p = x' - x'$$

Calculation of spatial coordinates „normal case”



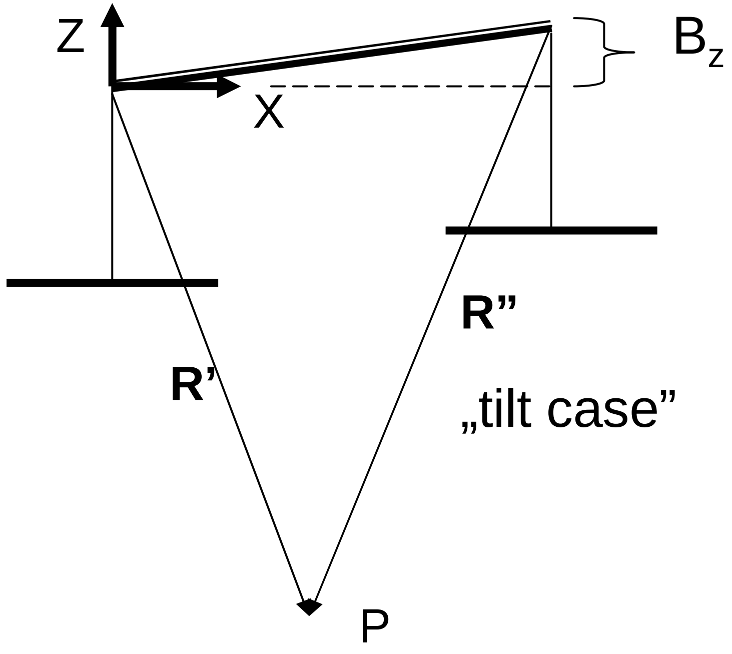
Normal case

Camera axes parallel and perpedicular to the base A’, A” – unit matrix (ω‘=φ‘=κ‘=ω”=φ”=κ”=0), B_x =B, B_y =B_z =0

$$R' = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{B}{(x' - x'')} \cdot \begin{bmatrix} x' \\ y' \\ -c_k \end{bmatrix} = \frac{B}{p} \cdot \begin{bmatrix} x' \\ y' \\ -c_k \end{bmatrix}$$

$$x' - x'' = p$$

Calculation of spatial coordinates on the base on airborne stereopair



Camera axes parallel to each other and to the reference coordinate system, A’, A” – unit matrix (ω‘=φ‘=κ‘=ω”=φ”=κ”=0)

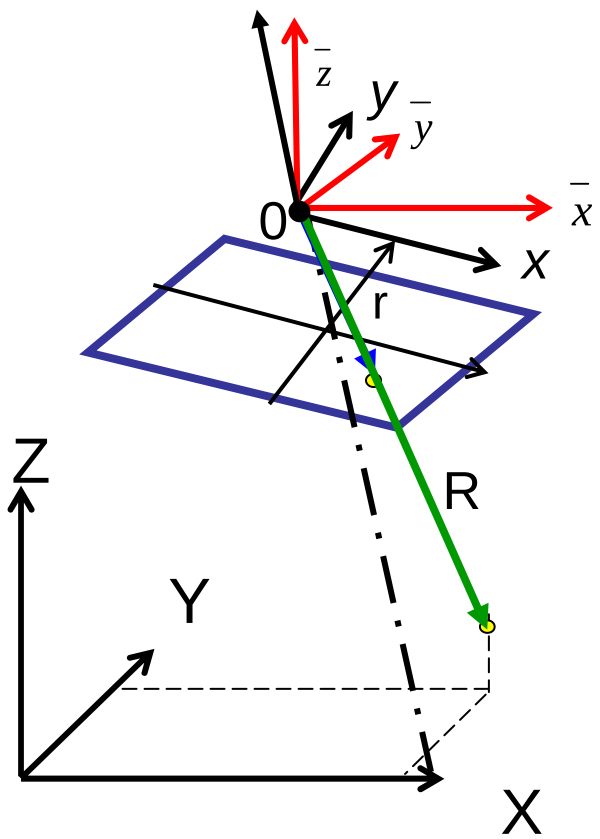
$$R' = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{B_x c_k - B_z x''}{(x' - x'') \cdot c_k} \cdot \begin{bmatrix} x' \\ y' \\ -c_k \end{bmatrix}$$

$$x' - x'' = p$$

$$B = \begin{bmatrix} B_x \\ B_y \\ B_z \end{bmatrix}$$

Calculation of spatial coordinates on the base on airborne stereopair

equivalent images



$$x_e = -c_{ke}\frac{a_{11}x + a_{12}y - a_{13}c_k}{a_{31}x + a_{32}y - a_{33}c_k}$$

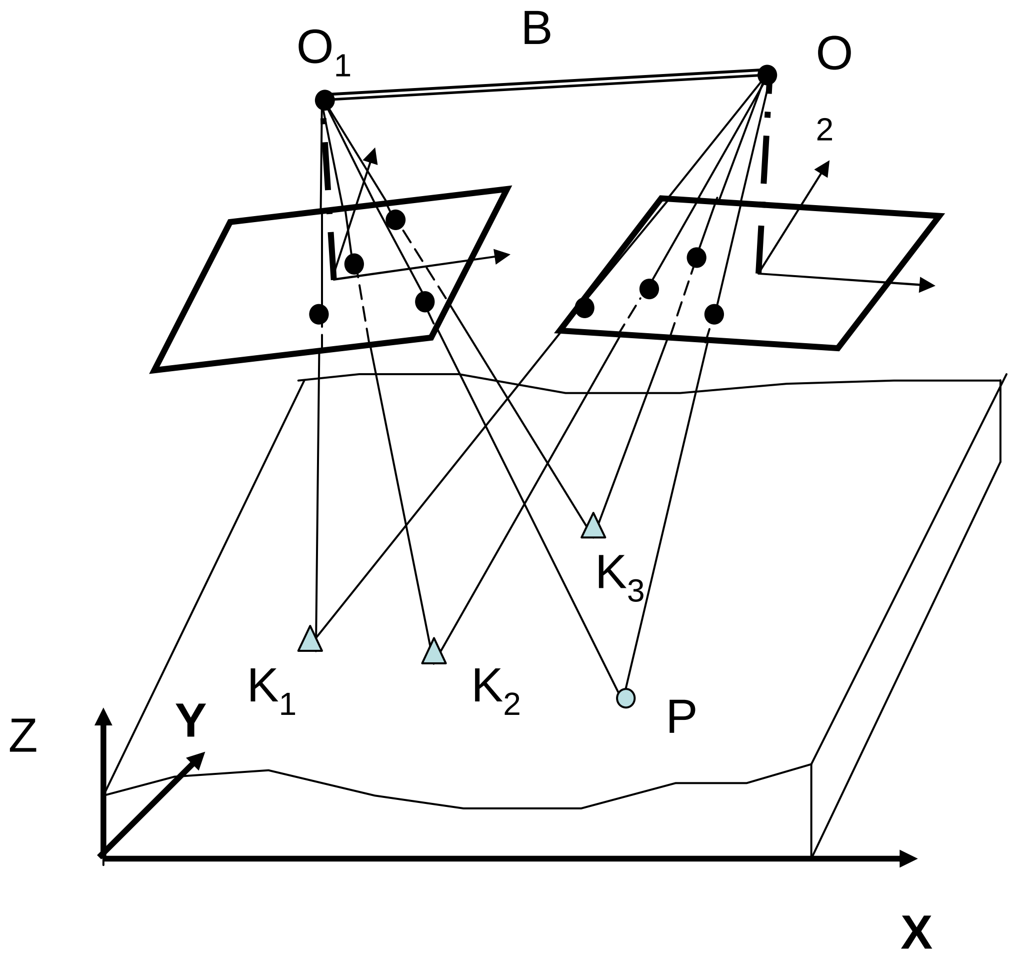
$$y_e = -c_{ke}\frac{a_{21}x + a_{22}y - a_{23}c_k}{a_{31}x + a_{32}y - a_{33}c_k}$$

Solution by tilt images

$$R' = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \frac{B_x c_k - B_z x_e^{''}}{(x_e^{'} - x_e^{''}) \cdot c_k} \cdot \begin{bmatrix} x_e^{'} \\ y_e^{'} \\ -c_k \end{bmatrix}$$

$$x_e^{'} - x_e^{''} = p$$

Calculation of spatial coordinates on the base on airborne stereopair



Disadvantages of equivalent images method

- Crossection of homologus beams is not applied (i.e. to the point P)
- On each image should be at least 3 points
- If these points are the same on both images it is not favourable for the back calculation

Collinearity equation: general case

$$x_{zdj} - x_0 + \Delta x = -c_k \frac{a_{11}(X - X_0) + a_{21}(Y - Y_0) + a_{31}(Z - Z_0)}{a_{13}(X - X_0) + a_{23}(Y - Y_0) + a_{33}(Z - Z_0)}$$

$$y_{zdj} - y_0 + \Delta y = -c_k \frac{a_{12}(X - X_0) + a_{22}(Y - Y_0) + a_{32}(Z - Z_0)}{a_{13}(X - X_0) + a_{23}(Y - Y_0) + a_{33}(Z - Z_0)}$$

$$x_{zdj} = x_0 - \Delta x - c_k \frac{a_{11}(X - X_0) + a_{21}(Y - Y_0) + a_{31}(Z - Z_0)}{a_{13}(X - X_0) + a_{23}(Y - Y_0) + a_{33}(Z - Z_0)} = F_x$$

$$y_{zdj} = y_0 - \Delta y - c_k \frac{a_{12}(X - X_0) + a_{22}(Y - Y_0) + a_{32}(Z - Z_0)}{a_{13}(X - X_0) + a_{23}(Y - Y_0) + a_{33}(Z - Z_0)} = F_y$$

$$\frac{\partial F_x}{\partial X_0} dX_0 + \frac{\partial F_x}{\partial Y_0} dY_0 + \frac{\partial F_x}{\partial Z_0} dZ_0 + \frac{\partial F_x}{\partial \omega} d\omega + \frac{\partial F_x}{\partial \varphi} d\varphi + \frac{\partial F_x}{\partial \kappa} d\kappa +$$

$$+ \frac{\partial F_x}{\partial X} dX + \frac{\partial F_x}{\partial Y} dY + \frac{\partial F_x}{\partial Z} dZ + F_x^0 - x_{zdj} = v_x$$

$$\frac{\partial F_y}{\partial X_0} dX_0 + \frac{\partial F_y}{\partial Y_0} dY_0 + \frac{\partial F_y}{\partial Z_0} dZ_0 + \frac{\partial F_y}{\partial \omega} d\omega + \frac{\partial F_y}{\partial \varphi} d\varphi + \frac{\partial F_y}{\partial \kappa} d\kappa +$$

$$+ \frac{\partial F_y}{\partial X} dX + \frac{\partial F_y}{\partial Y} dY + \frac{\partial F_y}{\partial Z} dZ + F_y^0 - y_{zdj} = v_y$$

Calculation of spatial coordinates on the base on airborne stereopair – genaral solution

Set of measurements equations after linearyzacji :

$$v_{x'} = \hat{x}'\left(\hat{X},\hat{Y},\hat{Z},\boxed{x_0,y_0,c_k},\hat{X}_0^{'},\hat{Y}_0^{'},\hat{Z}_0^{'},\hat{\omega}',\hat{\varphi}',\hat{\kappa}'\right)-x'$$

$$v_{y'} = \hat{y}'\left(\hat{X},\hat{Y},\hat{Z},\boxed{x_0,y_0,c_k},\hat{X}_0^{'},\hat{Y}_0^{'},\hat{Z}_0^{'},\hat{\omega}',\hat{\varphi}',\hat{\kappa}'\right)-y'$$

$$v_{x''} = \hat{x}''\left(\hat{X},\hat{Y},\hat{Z},\boxed{x_0,y_0,c_k},\hat{X}_0^{''},\hat{Y}_0^{''},\hat{Z}_0^{''},\hat{\omega}'',\hat{\varphi}'',\hat{\kappa}''\right)-x''$$

$$v_{y''} = \hat{y}''\left(\hat{X},\hat{Y},\hat{Z},\boxed{x_0,y_0,c_k},\hat{X}_0^{''},\hat{Y}_0^{''},\hat{Z}_0^{''},\hat{\omega}'',\hat{\varphi}'',\hat{\kappa}''\right)-y''$$

....

$$v_X = \hat{X} - X$$

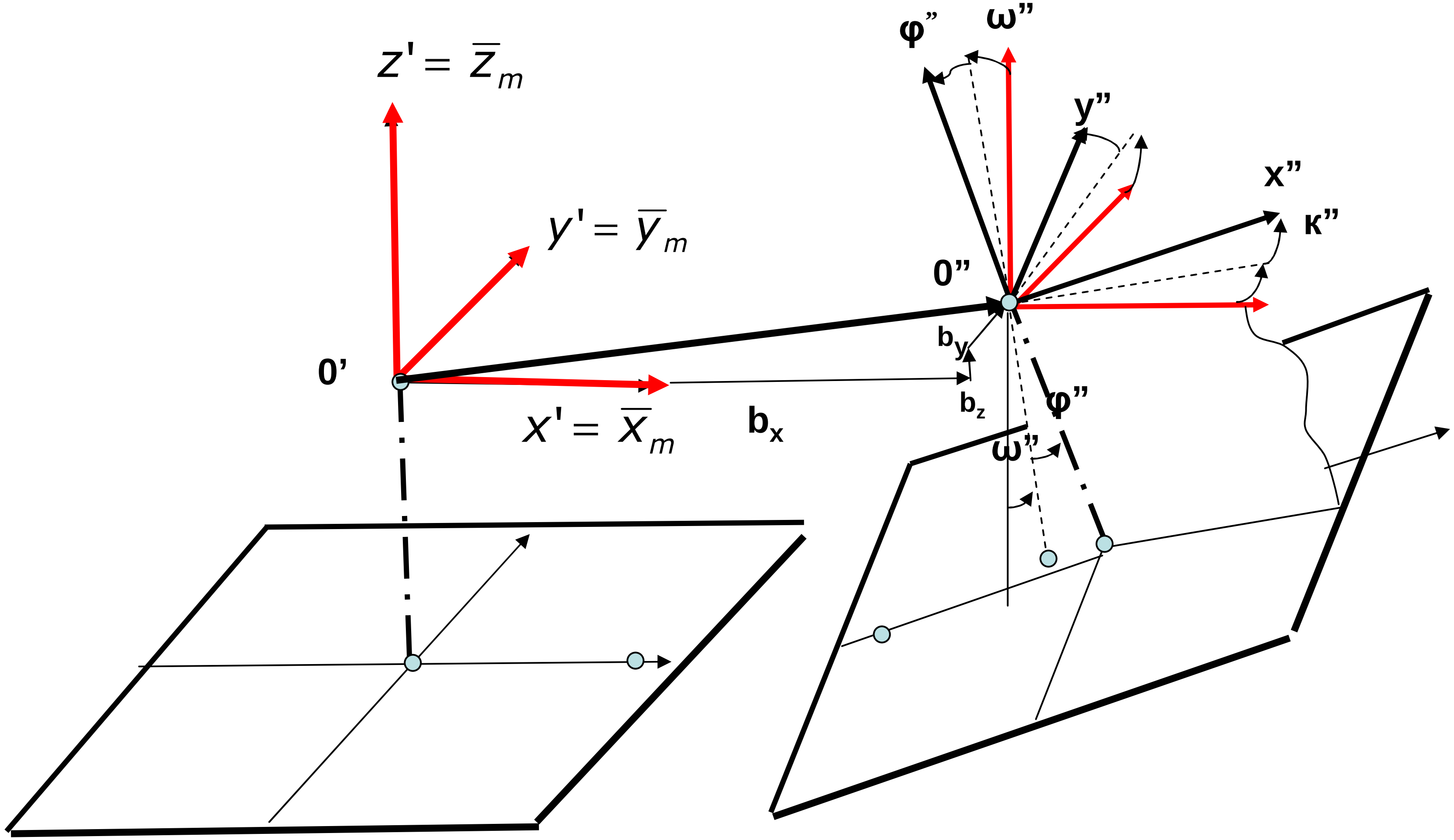
$$v_Y = \hat{Y} - Y$$

$$v_Z = \hat{Z} - Z$$

n_P – numbers of unknown object points
n_{XYZ}, n_{XY}, n_Z – numbers of full GCP (XYZ), horisontal GCP (XY), Z-points,
n – numbers of equations = $4n_P+3n_{XYZ}+2n_{XY}+n_Z$
u – number of unknowns = $3n_P+12$
$n – u = 3n_{XYZ}+2n_{XY}+n_Z+n_{p.}-12$

Analytical medel creation on the base on airborne images – model coordinate system

Model coordinate system is defined by left image

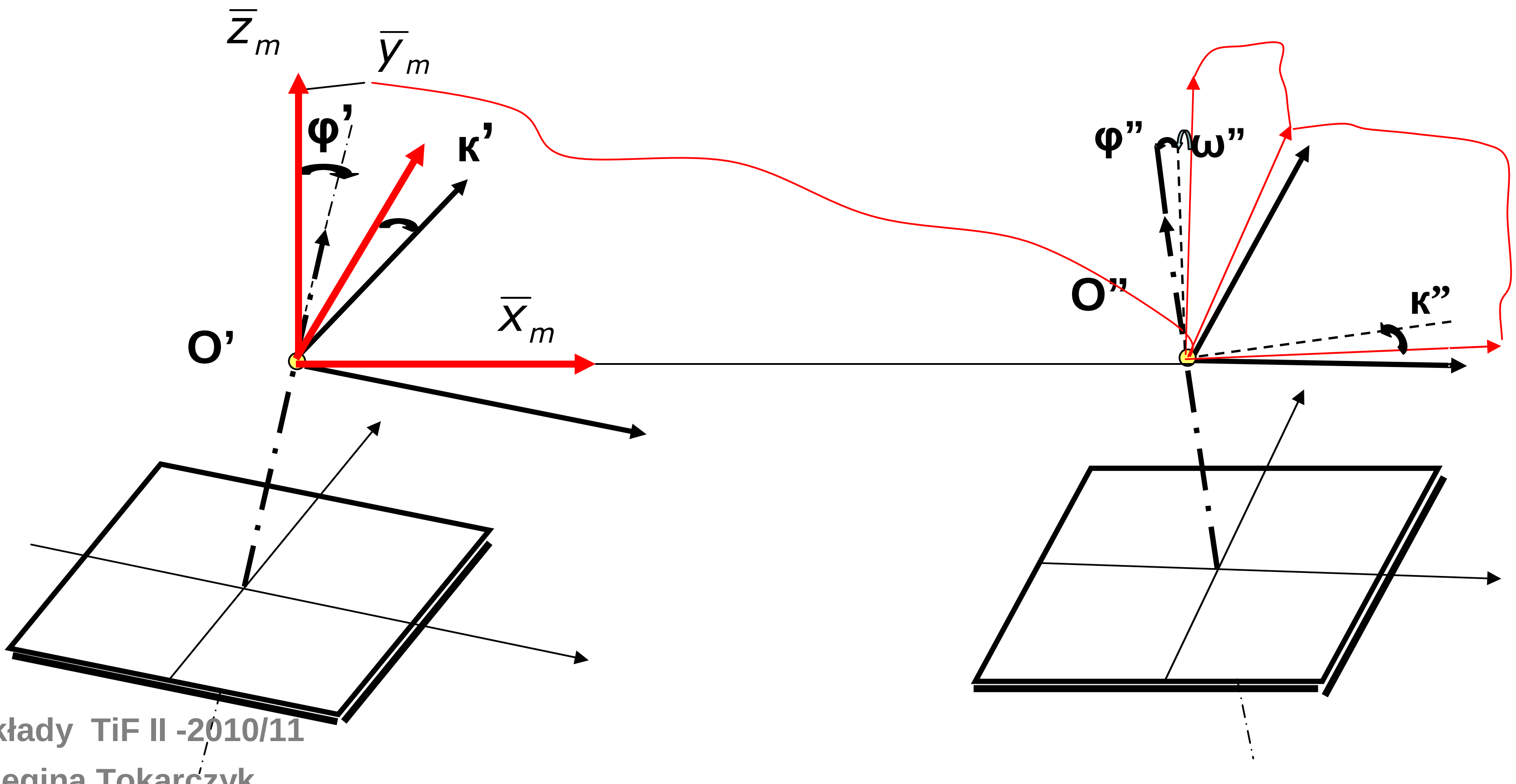


Unknowns: $\overline{y}_0'' = b_y, \overline{z}_0'' = b_z, \omega'', \varphi'', \kappa''$

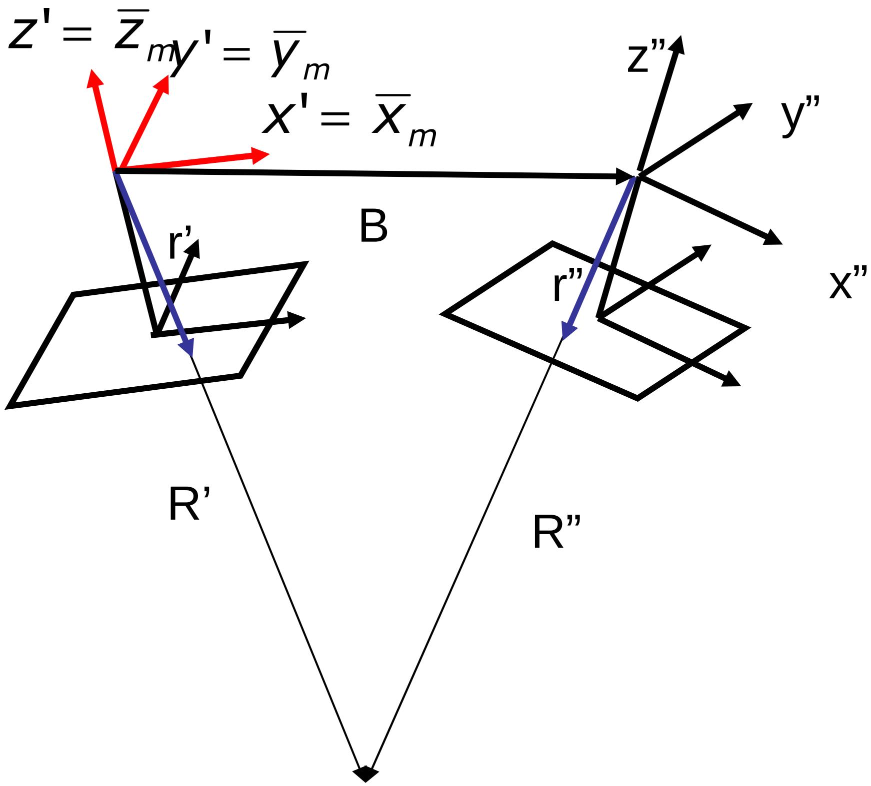
Analytical medel creation on the base on airborne images – model coordinate system

Model coordinate system – connected with the base

Unknowns: $\varphi', \kappa', \omega'', \varphi'', \kappa''$



Analytical model creation on the base on airborne images



Complanarity condition: b, r’ i r”:

$$B(R' \times R'') = 0$$ What means that:

$$b(r' \times r'') = 0$$

$$\Delta = \begin{vmatrix} b_x & b_y & b_z \\ \bar{x}' & \bar{y}' & \bar{z}' \\ \bar{x}'' & \bar{y}'' & \bar{z}'' \end{vmatrix} = 0$$

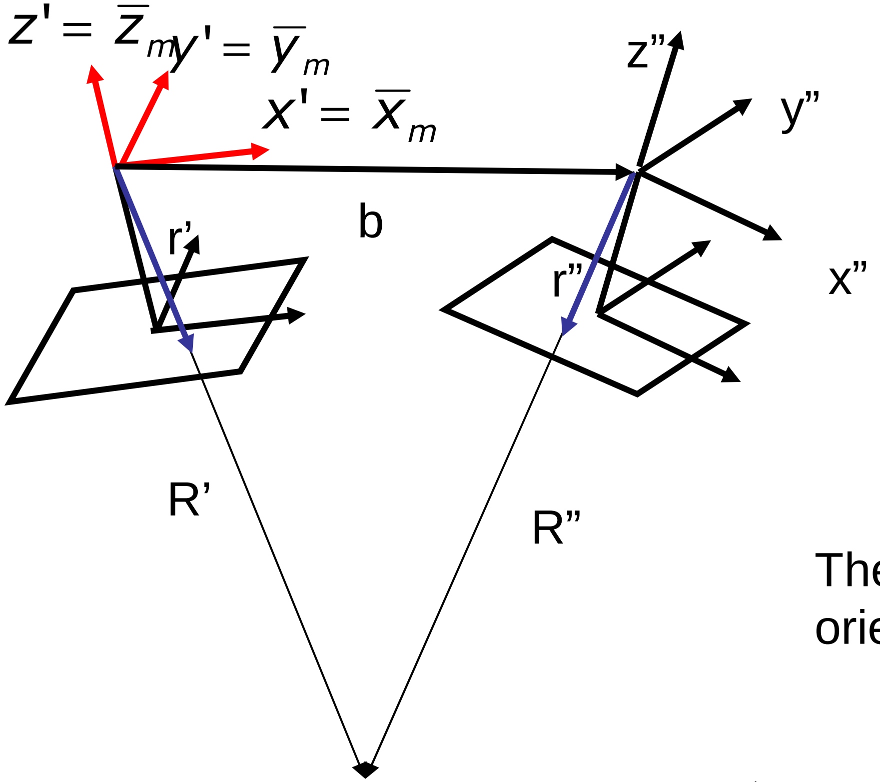
$$\begin{vmatrix} \bar{x}' \\ \bar{y}' \\ \bar{z}' \end{vmatrix} = A' \begin{vmatrix} x' \\ y' \\ z' = -c_k \end{vmatrix}$$

$$\begin{vmatrix} \bar{x}'' \\ \bar{y}'' \\ \bar{z}'' \end{vmatrix} = \begin{vmatrix} b_x \\ b_y \\ b_z \end{vmatrix} + A'' \begin{vmatrix} x'' \\ y'' \\ z'' = -c_k \end{vmatrix}$$

The following unknowns are in coordinate system of the model calculated from right image b_x, b_Y, b_Z, ω”,φ”,κ”

Analytical relative orientation

Analytical model creation on the base on airborne images



For model coordinate system

$$A' = \begin{vmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{vmatrix}$$

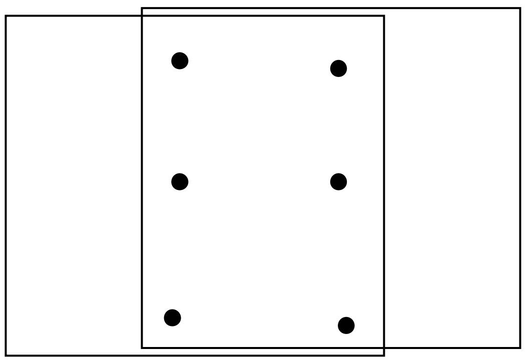
The angle elements of right image orientation are small, so:

$$A'' = \begin{vmatrix} 1 & -d\kappa & d\varphi \\ d\kappa & 1 & -d\omega \\ -d\varphi & d\omega & 1 \end{vmatrix}$$

(so called matrix of small rotation angles)

Analytical model creation on the base on airborne images

We assume b_x as a free value because it influences only on the scale of created model. For each homologus pairs measured on the image of coordinates x’, y’, x”, y” measurements equations based on complanarity condition are prepared. There are 5 unknowns: b_y, b_z, dω=ω”, dφ=φ”, dκ=κ” in the equations. So at least 5 homologus pairs points should be measured. They are measured near so called Gruber’s areas:



After unknowns calculation of relative model orientation the model is created.

$$\begin{vmatrix}\bar{x}'_m\\ \bar{y}'_m\\ \bar{z}'_m\end{vmatrix} = \begin{vmatrix}\bar{x}'_0\\ \bar{y}'_0\\ \bar{z}'_0\end{vmatrix} + \lambda' \begin{vmatrix}\bar{x}'-\bar{x}'_0\\ \bar{y}'-\bar{y}'_0\\ \bar{z}'-\bar{z}'_0\end{vmatrix} \qquad \begin{vmatrix}\bar{x}''_m\\ \bar{y}''_m\\ \bar{z}''_m\end{vmatrix} = \begin{vmatrix}\bar{x}''_0\\ \bar{y}''_0\\ \bar{z}''_0\end{vmatrix} + \lambda'' \begin{vmatrix}\bar{x}''-\bar{x}''_0\\ \bar{y}''-\bar{y}''_0\\ \bar{z}''-\bar{z}''_0\end{vmatrix}$$

Analytical model creation on the base on airborne images

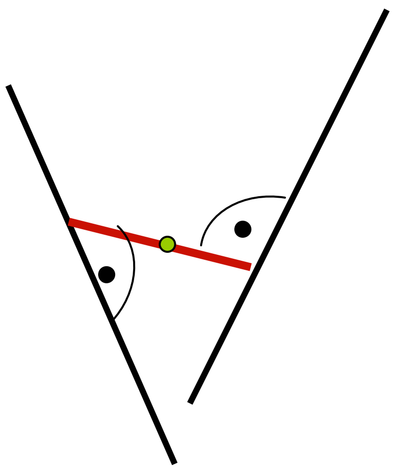
There are in these equations two unknowns λ' i λ'' which are determined assuming that model coordinates calculated from two ways (from three possible) are equal.

$$\bar{x}'_m = \bar{x}''_m$$
$$\bar{z}'_m = \bar{z}''_m \quad \Rightarrow \quad \lambda', \lambda''$$

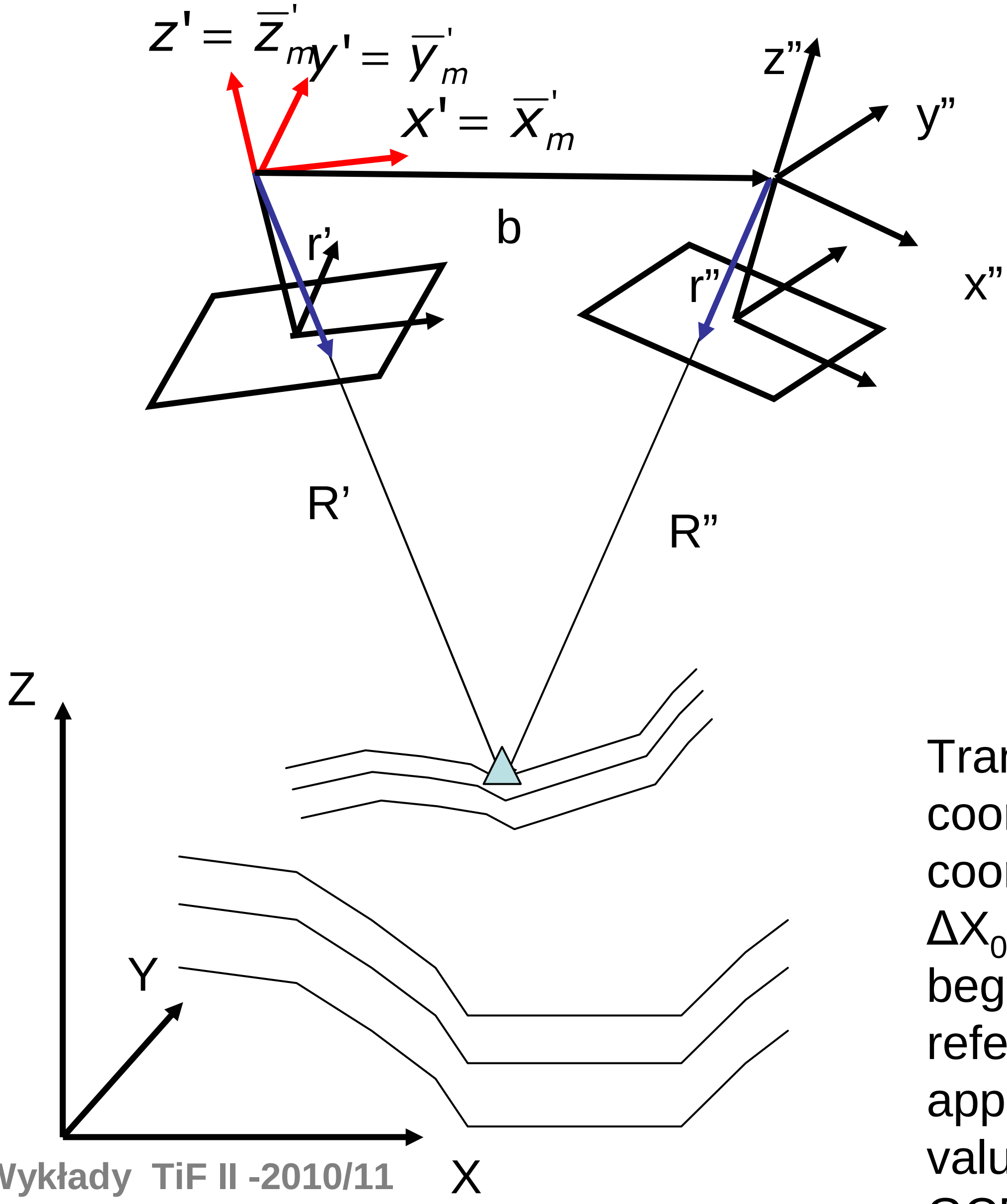
Lateral parallax is an idicator of performing model orientation.

$$p_y = \bar{y}''_m - \bar{y}'_m$$

Point of the model, determined by two ways, we calculated according presented way.



Analytical absolute orientation

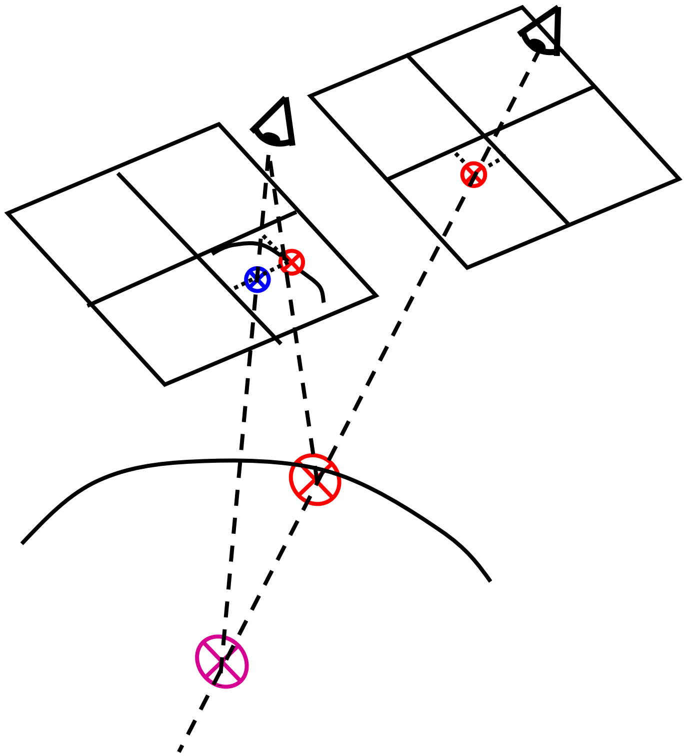


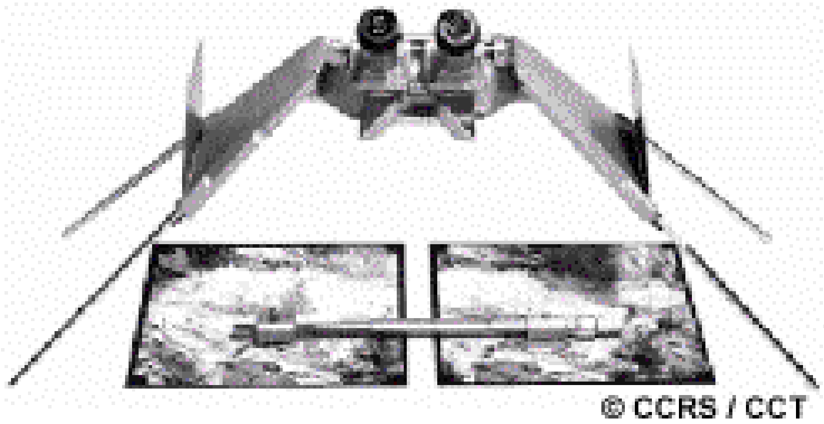
$$\begin{vmatrix} X \\ Y \\ Z \end{vmatrix} = \begin{vmatrix} \Delta X_0 \\ \Delta Y_0 \\ \Delta Z_0 \end{vmatrix} + s \cdot M \cdot \begin{vmatrix} \bar{x}_m \\ \bar{y}_m \\ \bar{z}_m \end{vmatrix}$$

$$M(\Omega, \Phi, K)$$

Transformation matrix from model coordinate system to the object coordinate system, s – scale coefficient, ΔX_0, ΔY_0, ΔZ_0, - coordinates of the beginning model coordinate system in reference coordinate system. GCPs are applied to the calculation of these values. There are 7 unknowns, so 3 GCPs are needed (9 equations)

Stereoploters - spatial measuring mark





Measuring marks are placed on the glasses of micrometer screw allow for hight difference measurements on the orientated model

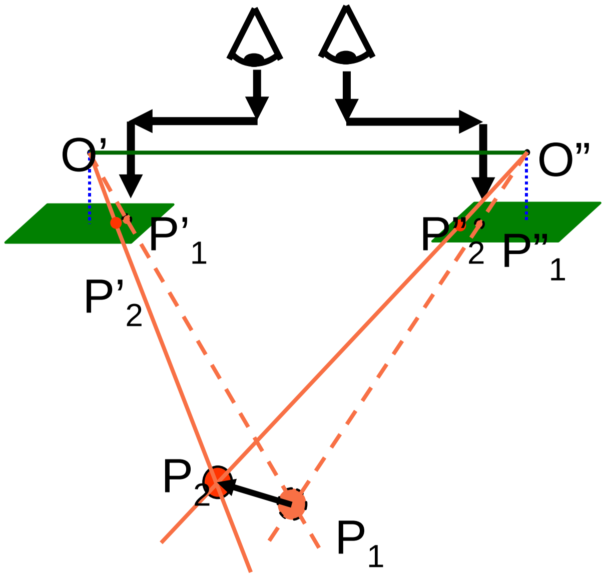
Principle of photogrametric images processing on stereoploter – steps

1. Creation of spatial model:
a) Interior orientation,
b) Relative orientation

2. Model orientation to the reference (object) coordinate system:
a) Scaling and leveling – analogue stereploters
b) Absolute orientation – analytical and digital stereploters

3. Sterodigitization

Principle of photogrametric images processing on stereoploter– management of measuring mark



$$\vec{r} = \lambda \cdot A \cdot \vec{R}$$

Known after relative or absolute orientation.

We calculate – shows us location of the mark on the images

$$x_{zdj} = x_0 - \Delta x - c_k \frac{a_{11}(X - X_0) + a_{21}(Y - Y_0) + a_{31}(Z - Z_0)}{a_{13}(X - X_0) + a_{23}(Y - Y_0) + a_{33}(Z - Z_0)}$$

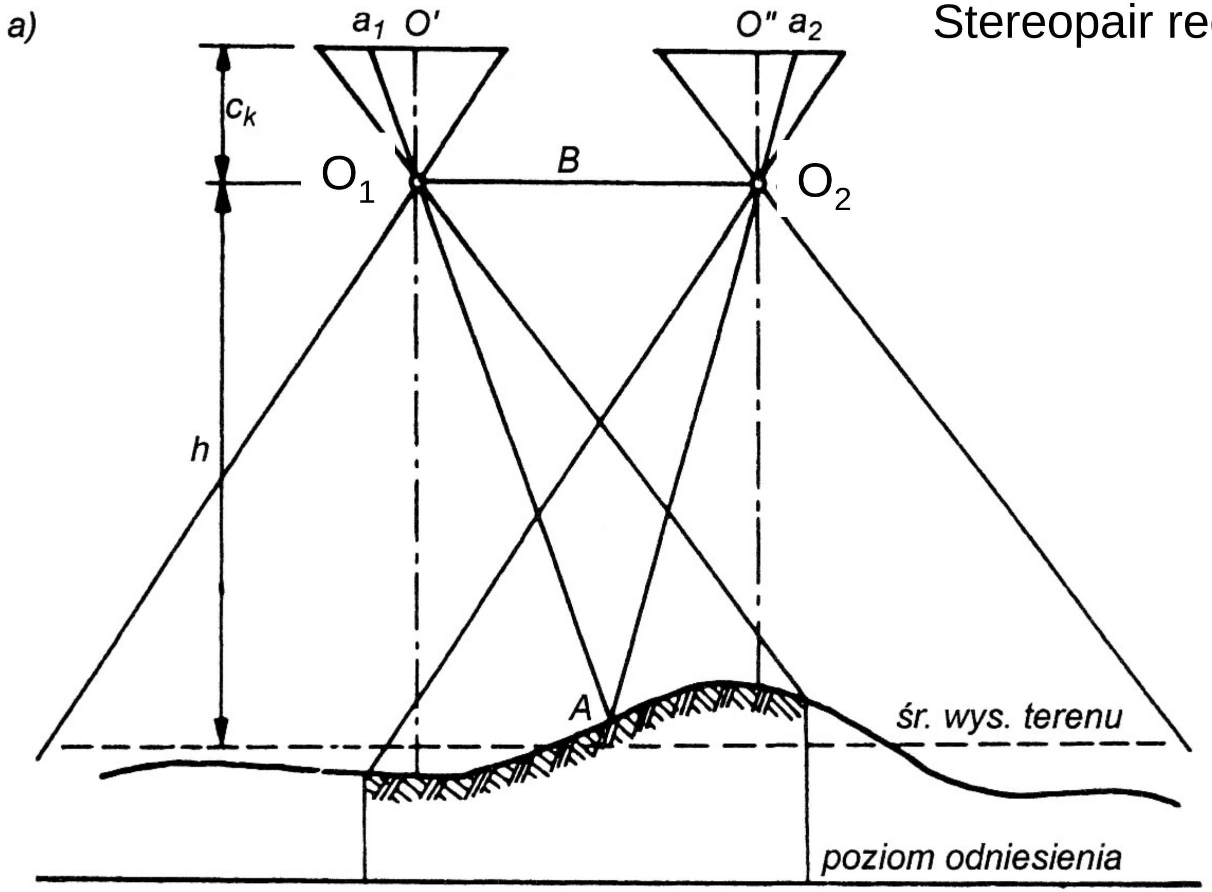
$$y_{zdj} = y_0 - \Delta y - c_k \frac{a_{12}(X - X_0) + a_{22}(Y - Y_0) + a_{32}(Z - Z_0)}{a_{13}(X - X_0) + a_{23}(Y - Y_0) + a_{33}(Z - Z_0)}$$

$$R = \begin{vmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{vmatrix}$$

We change shifting of the measuring mark

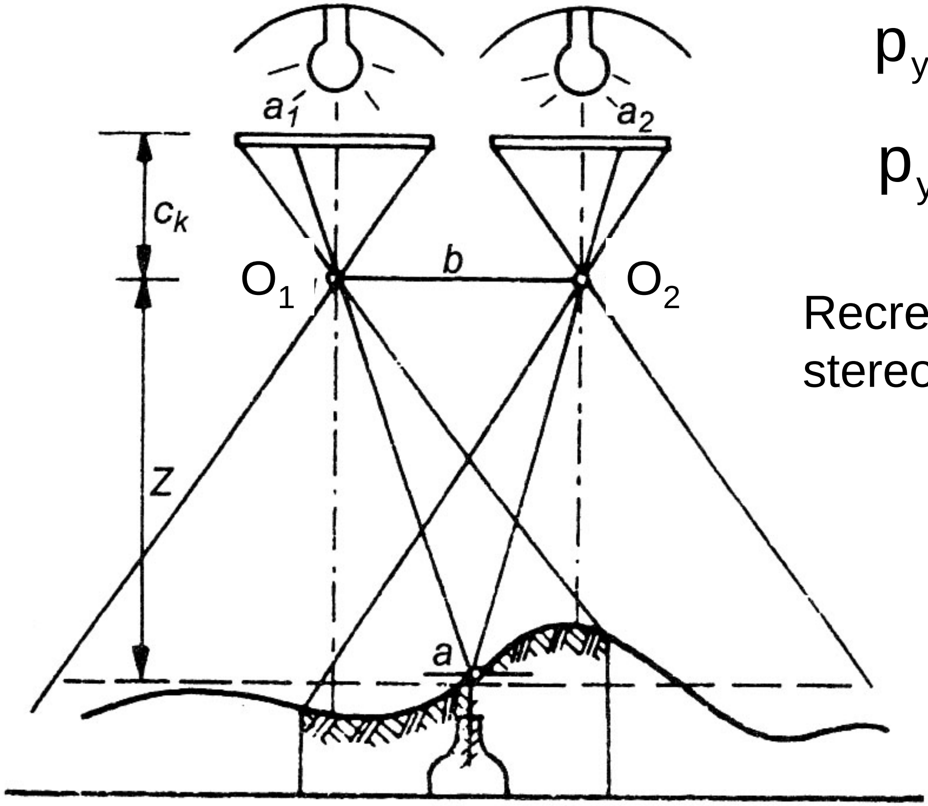
Known after relative or absolute orientation

Principle of photogrametric images processing on stereoploter



Stereopair registration

Principle of photogrametric images processing on stereoploter

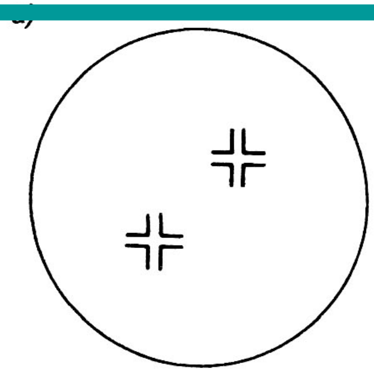


$$p_y = q = \bar{y}''_m - \bar{y}'_m$$

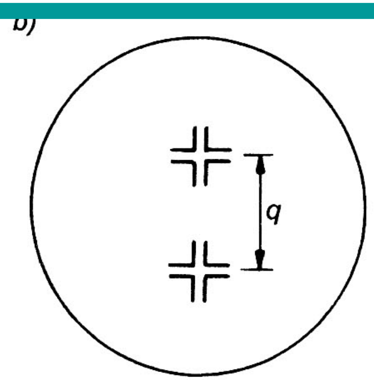
$$p_y = f(b_y, b_z, \omega'', \varphi'', \kappa'')$$

Recreation of the beam bundle in analogue stereoploter

Principle of photogrametric images processing on stereoploter

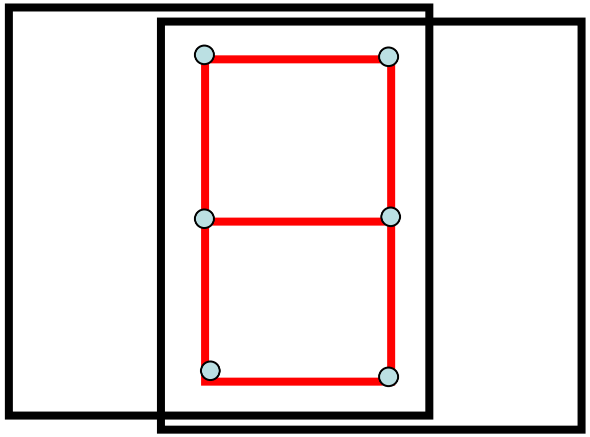


longitudinal and lateral



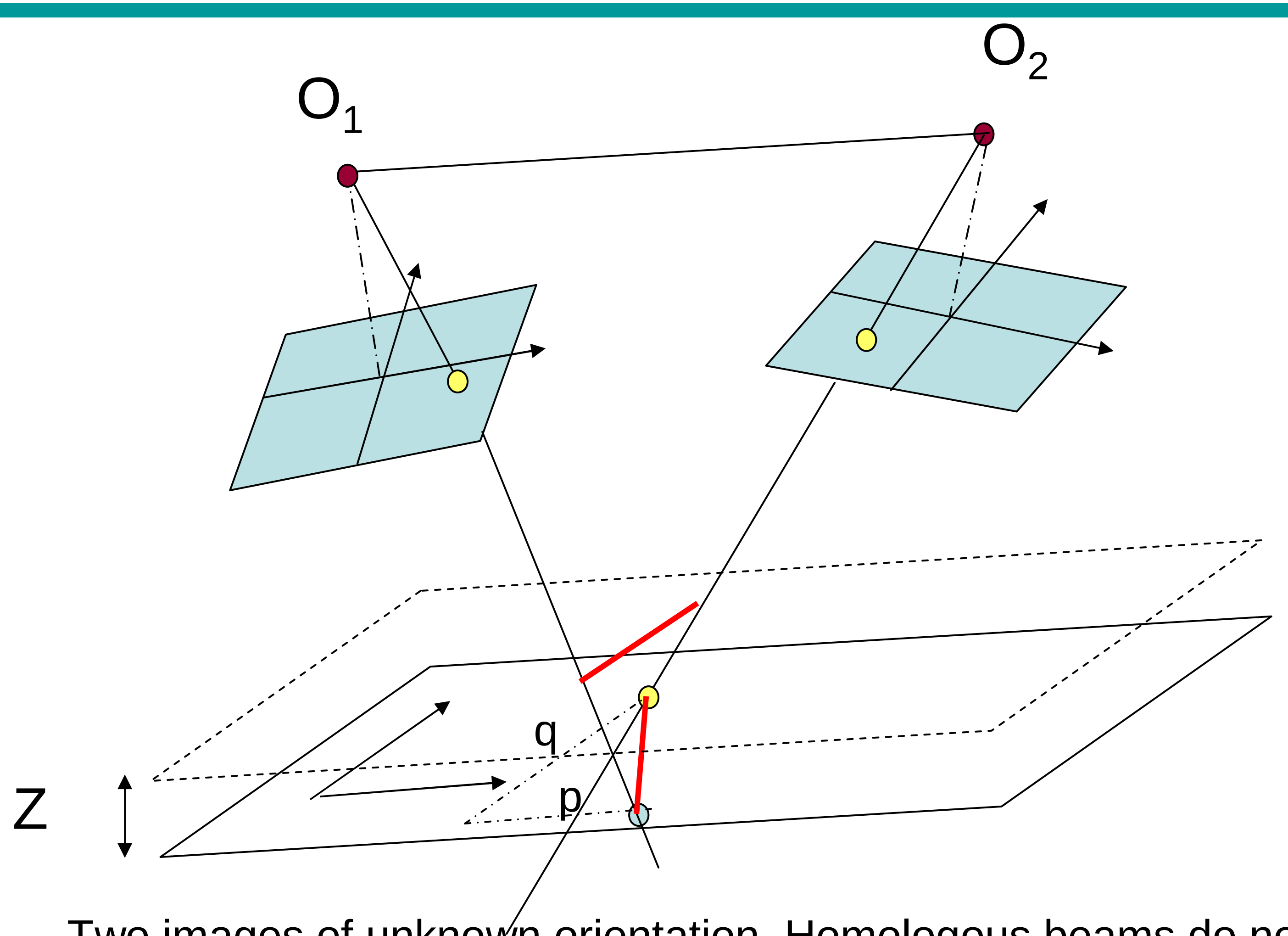
lateral

Parallax on the stereoscopic model



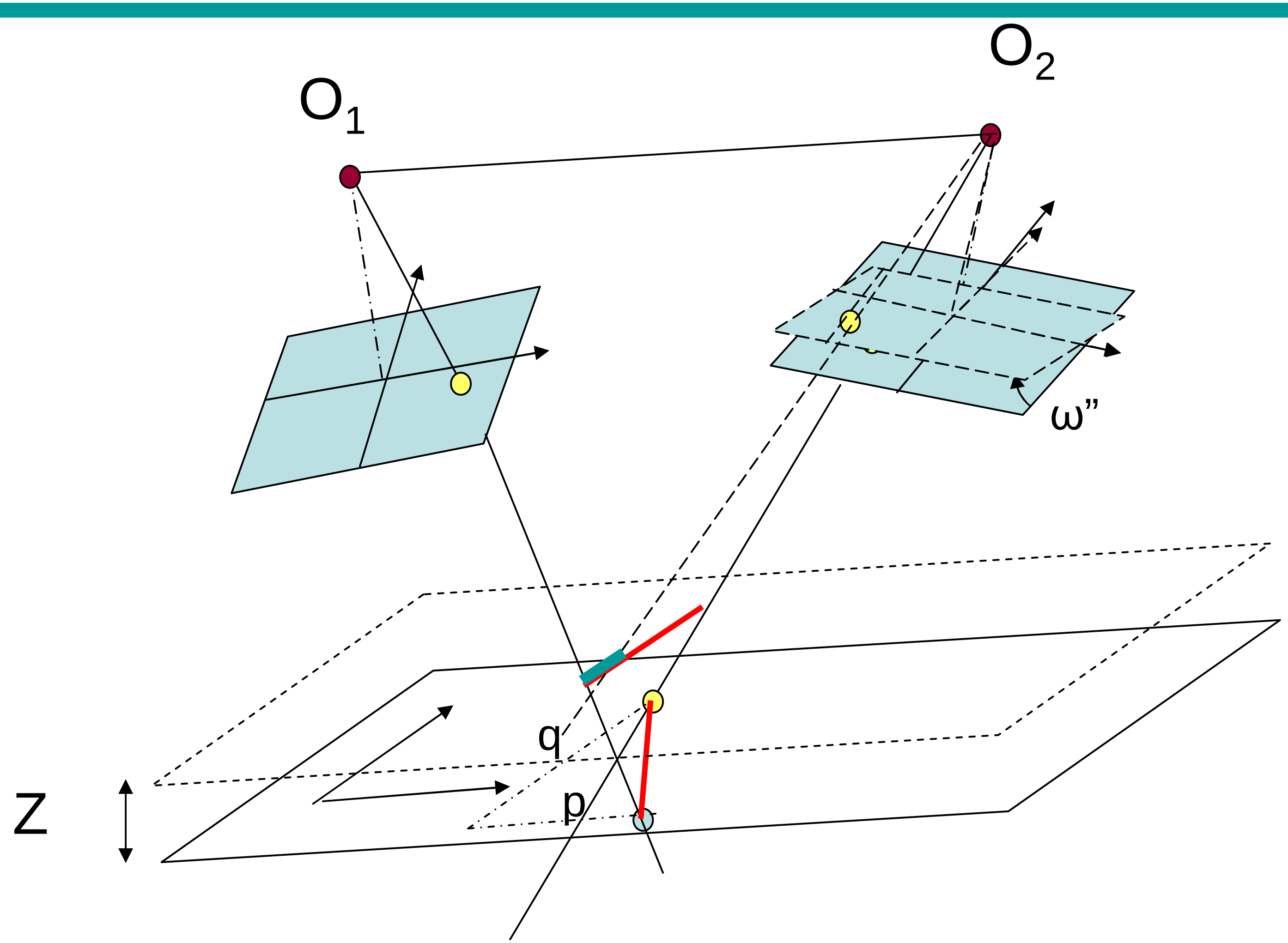
Gruber's areas

Principle of photogrametric images processing on stereoploter



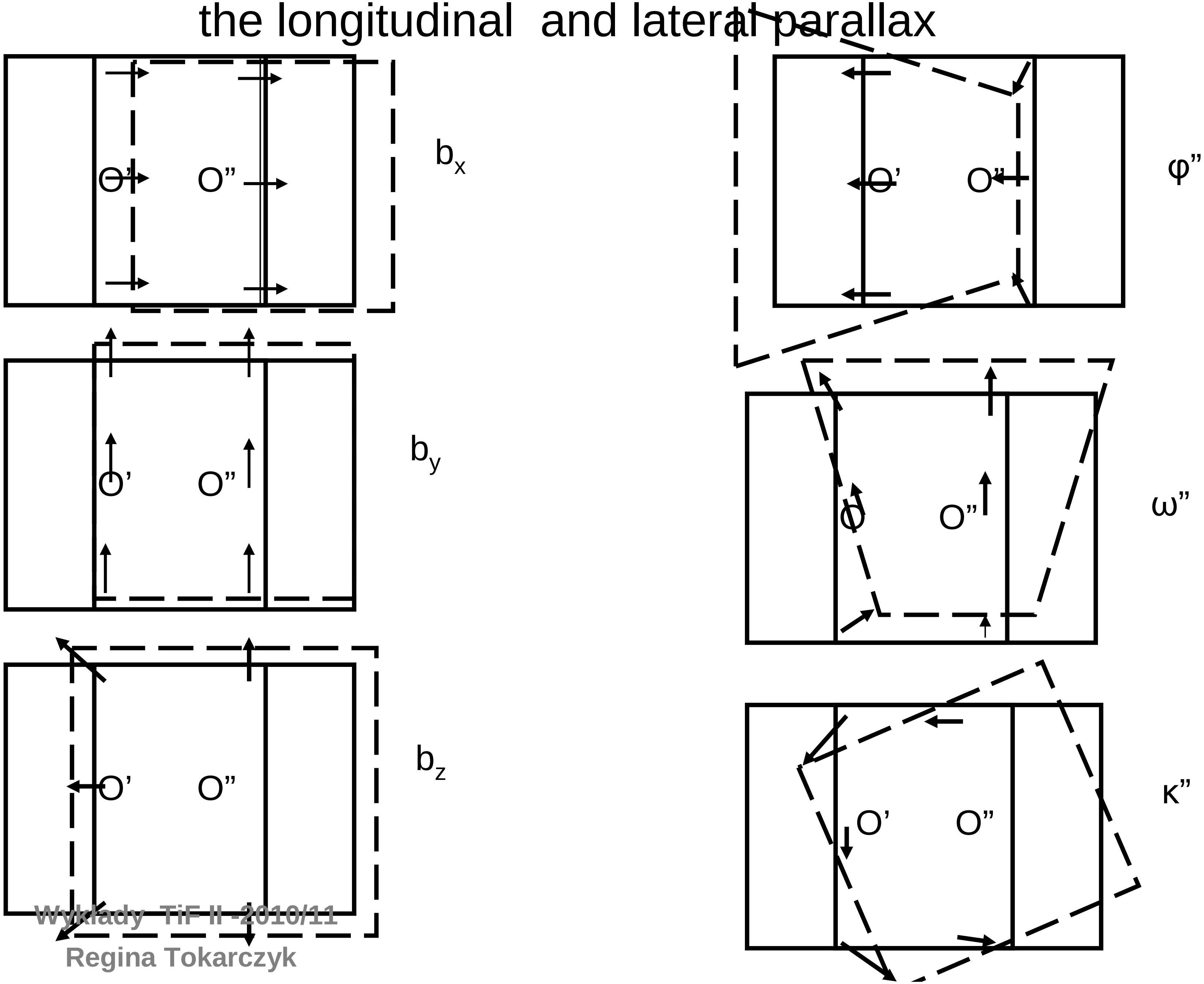
Two images of unknown orientation. Homologous beams do not cross. Crossing them with the plane Z we obtain two points. Vector connectiong them has to components: p longitudinal parallax and q lateral parallax. Changing of Z can provide to only lateral parallax.

Principle of photogrametric images processing on stereoploter

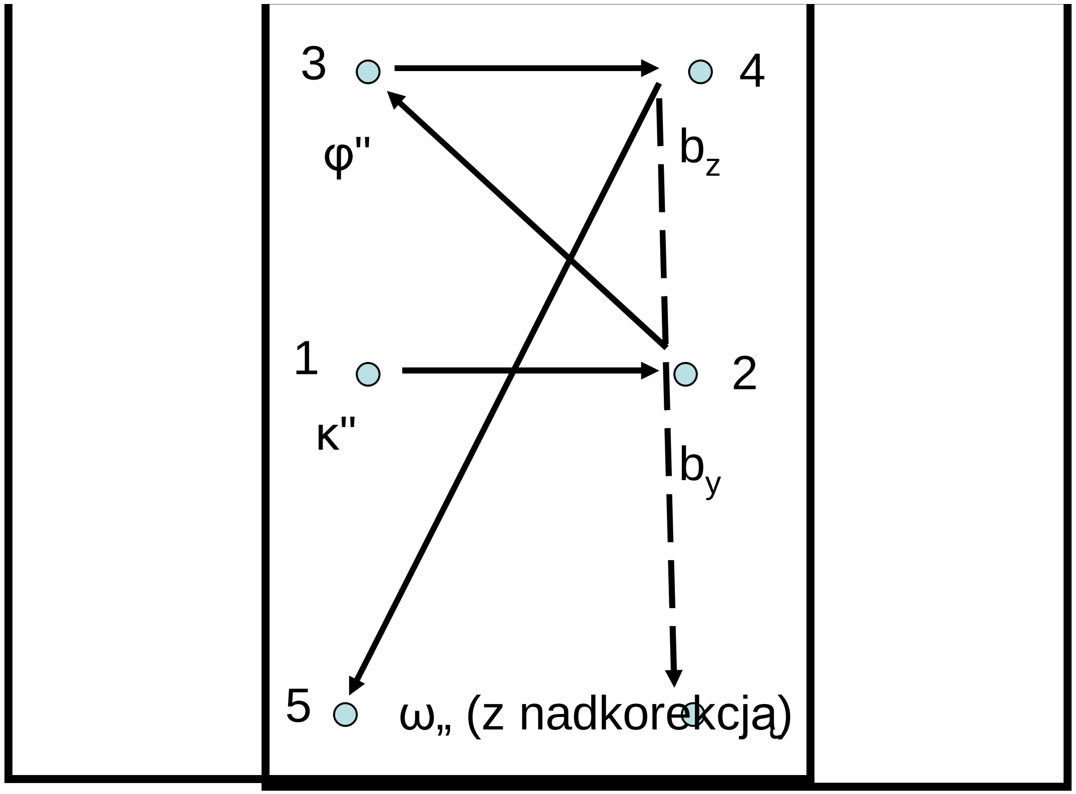


Changing linear and angle location of the camera we can change relative discrepancy of homologous points location. Here movement of right image ω we diminish or eliminate lateral paralax.

Influence of the changing of image location on the longitudinal and lateral parallax

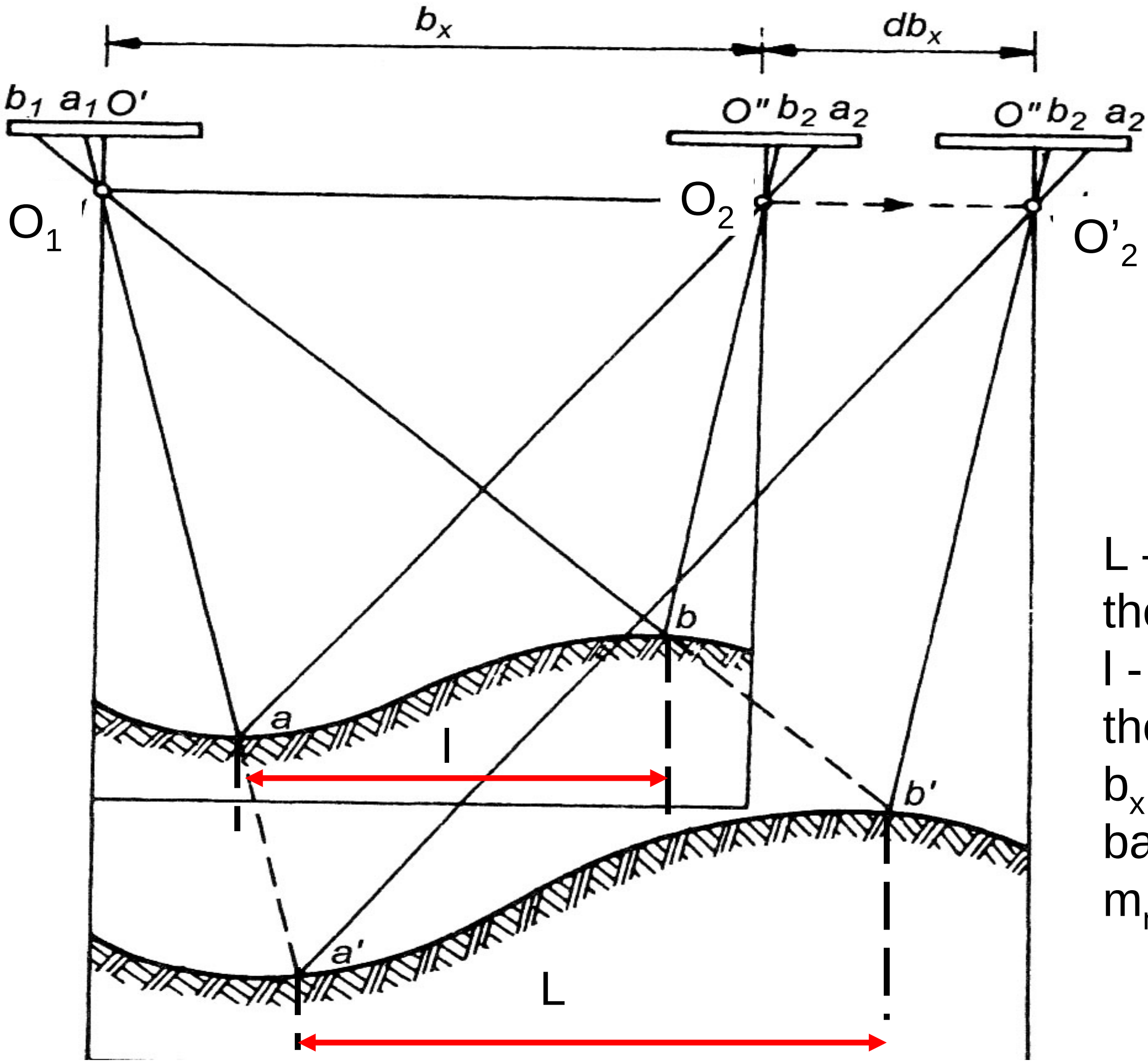


Principle of photogrametric images processing on analogue stereoploter



Lateral parallax is eliminated on the model by the movements of the right image (in the case to link the model with the left image) of by the movements of both images (in the case of model linking with the base). Lateral parallax is eliminated ineratively. Parallax in points 5th or 6th is not eliminated totally but some, calculated value is put. This is because in Grube's points there is not „pure" influence of individual movements.

Principle of photogrametric images processing on analogue stereoploter



$$k = \frac{L : m_{mod}}{l}$$

$$\overline{b}_x = b_x + db_x = b_x \cdot k$$

$$\overline{b}_y = b_y + db_y = b_y \cdot k$$

$$\overline{b}_z = b_z + db_z = b_z \cdot k$$

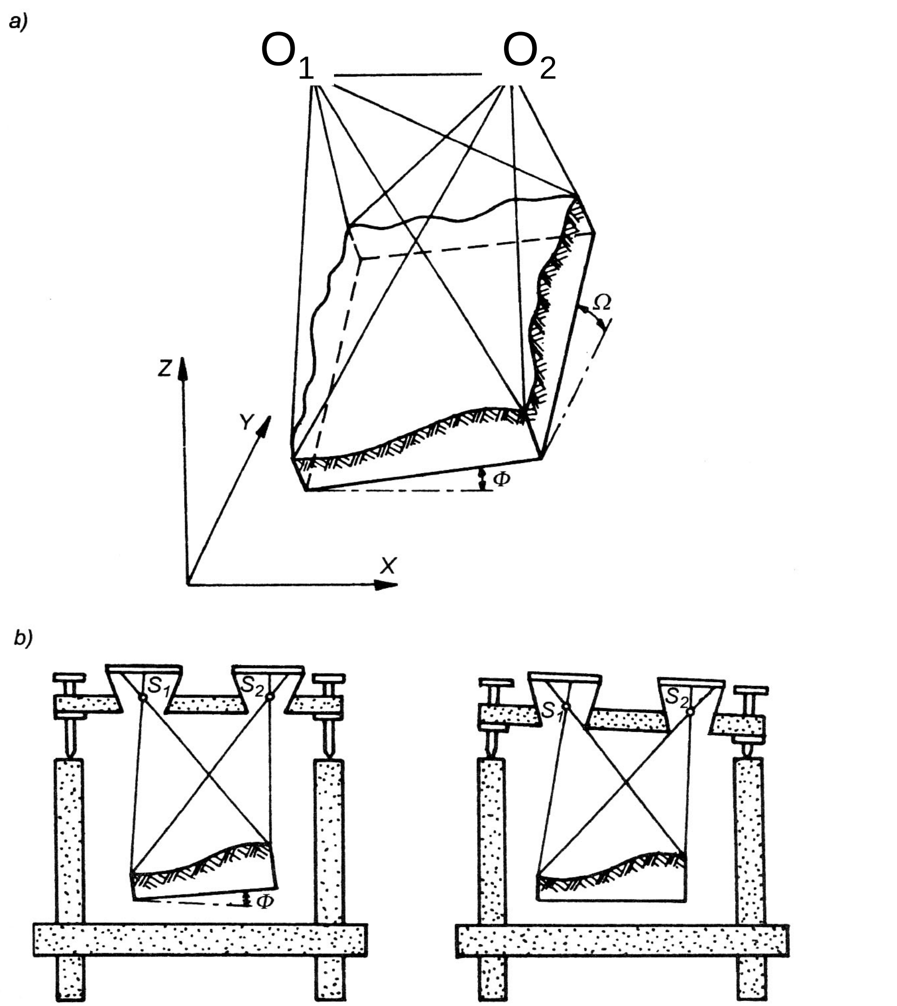
L – lenght of the section in the field

l - lenght of the section on the model

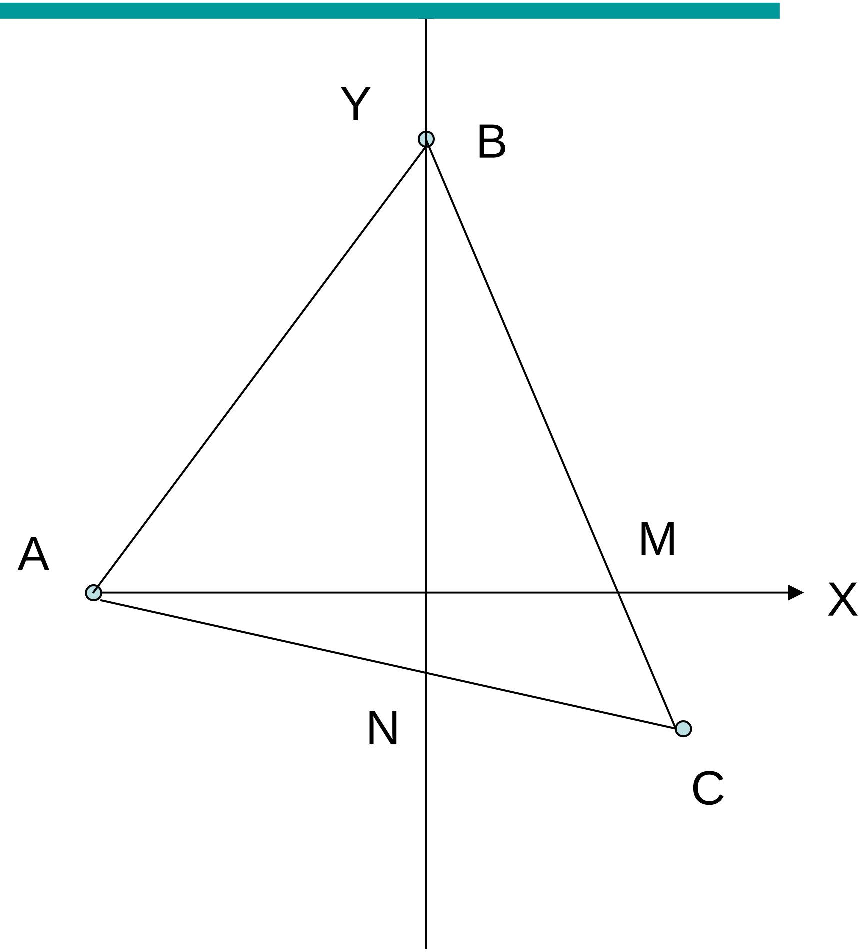
b_x – components of the base before scaling

m_{mod} – given model scale

Model scaling on the analogue stereoploter



5. Model terenu zrekonstruowany w przestrzeni autografu: a) przed poziomowaniem, b) przed i po nachyleniu podłużnym



$$\Phi = \left(\frac{\Delta Z_M - \Delta Z_A}{L_{AM}} \right) \cdot \rho^g$$

$$\Omega = \left(\frac{\Delta Z_N - \Delta Z_B}{L_{BN}} \right) \cdot \rho^g$$

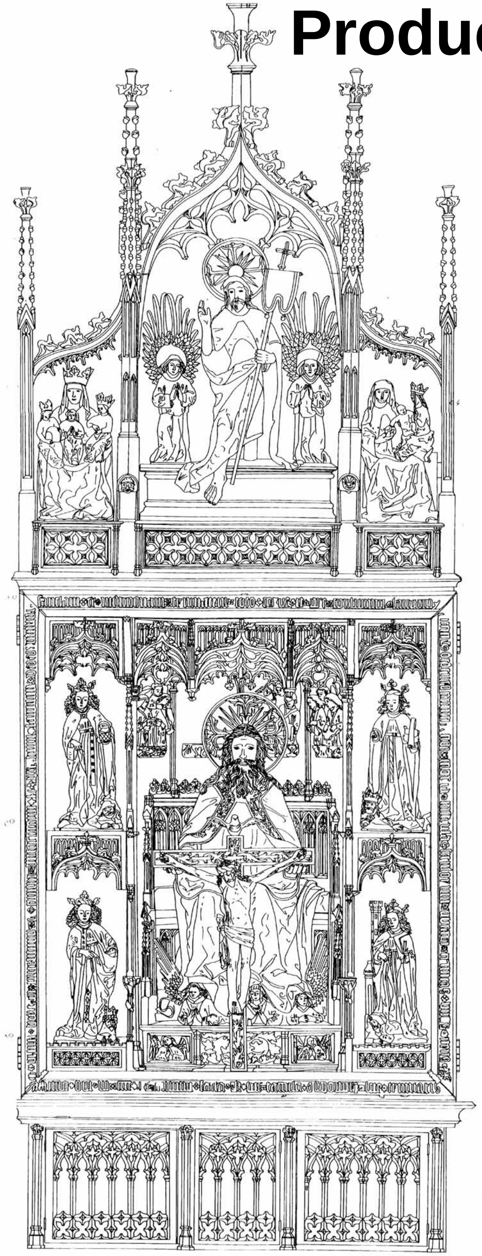
Principle of photogrametric images processing on stereoploter

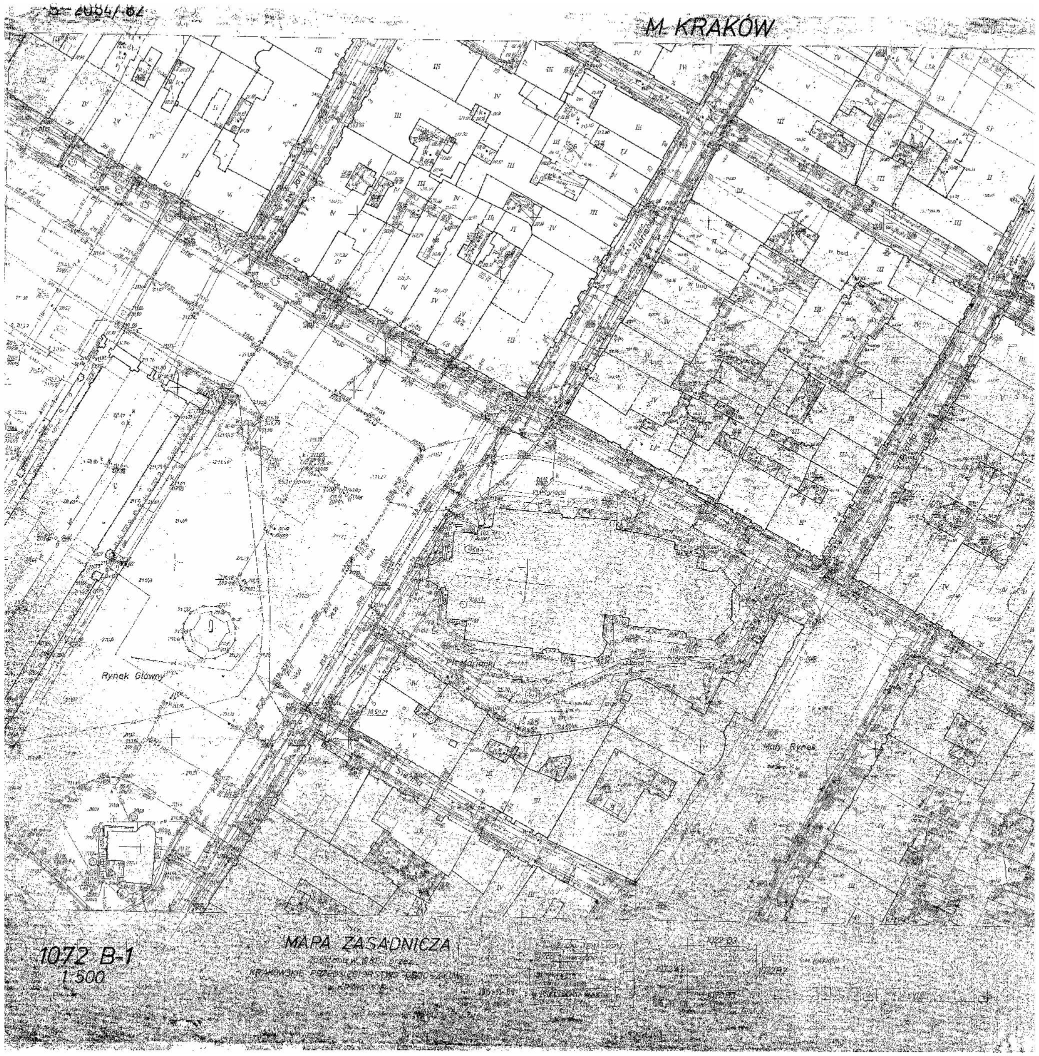
Steps on the analogue stereoploter

- Image centering on the carrier
- Model scale determination – depends on DTM and z-range of the stereoploter and transmition: model-mapping table.
- Relative orientation – lateral parallax elimination on the model in Gruber's points (iteratively)
- Model scaling – fixing components of the base on calculated from the distances between points on the model and in the field
- Model levelling – fixing of the model rotation angles calculated on the base on GCP coordiantes (model and field)
- Stereodigitization of the map content, objects or contour lines

Products of analogue stereoploter processing

Part of the Main Square in Cracow



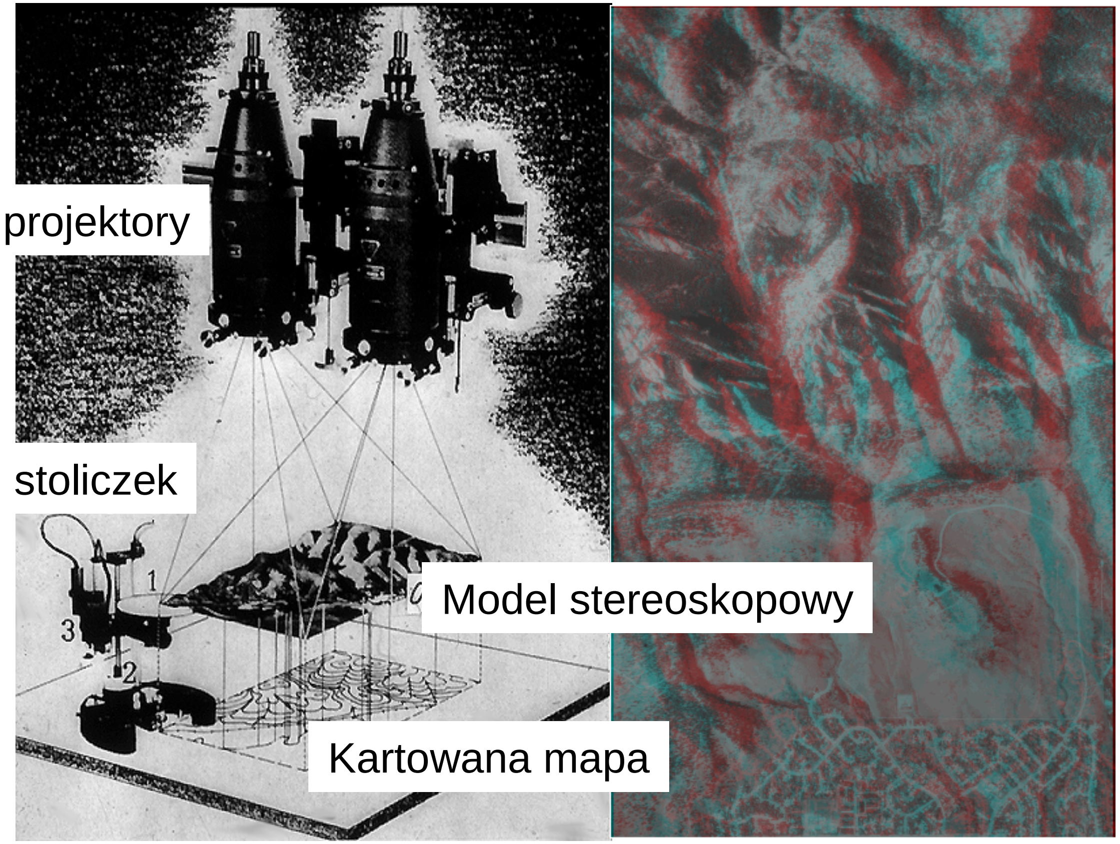


Plan of St. Trinity Altar Plan in Swietokrzyska Chapel in Wawel

Image recognition for stereoploting

Autograf oparty na zasadzie podwójnej projekcji

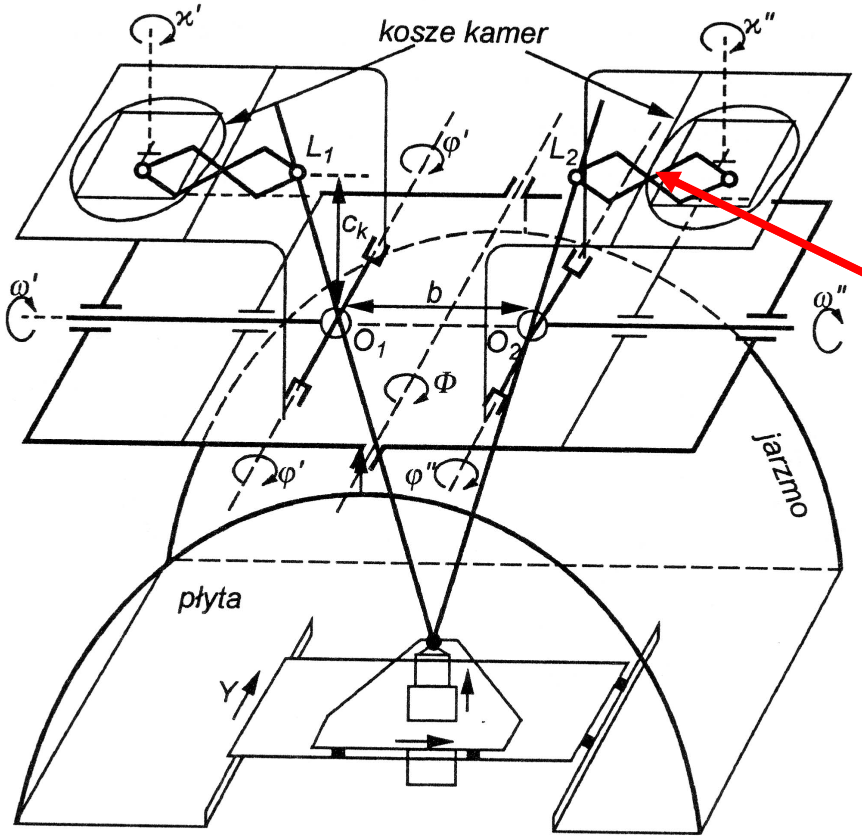
Do projektorów tzw multiplexu zakładano pomniejszone zdjęcia. Projektory będące odpowiednikiem kamer miały umożliwioną zmianę orientacji zewnętrznej. Na stół multiplexu rzutowany był podwójny obraz. Posługując się stoliczkiem pomocniczym o zmienianej wysokości usuwano paralaksę podłużną, a ruchami kamer w procesie orientacji wzajemnej - paralaksę poprzeczną. Założenie do projektorów filtrów i użycie do obserwacji okularów anaglifowych umożliwiało obserwację stereoskopową modelu.



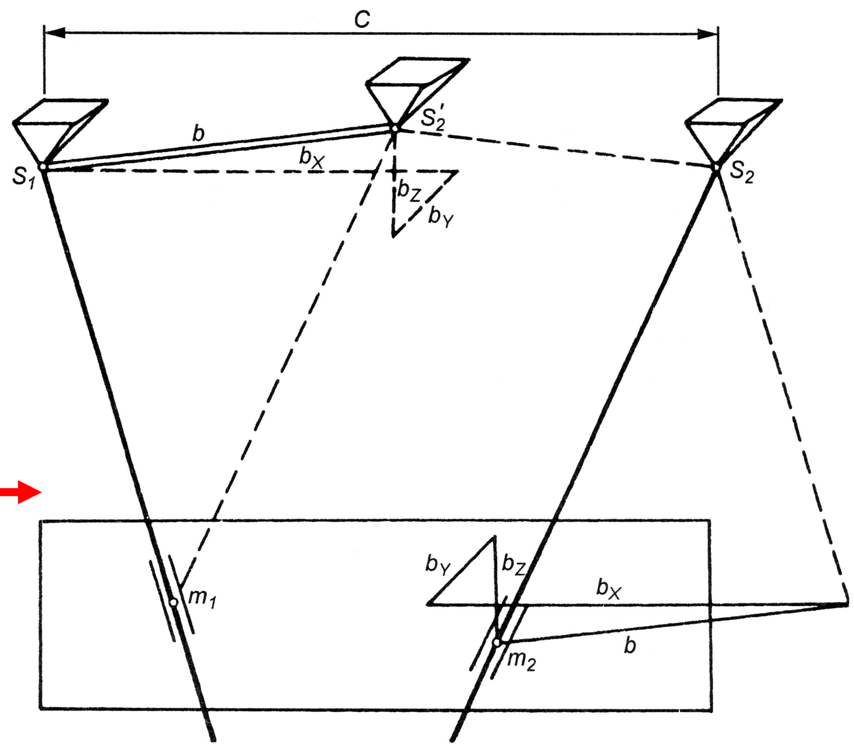
Stereoploters based on the machanical principle

Pronciple of the constuction of stereoploter Wild A8

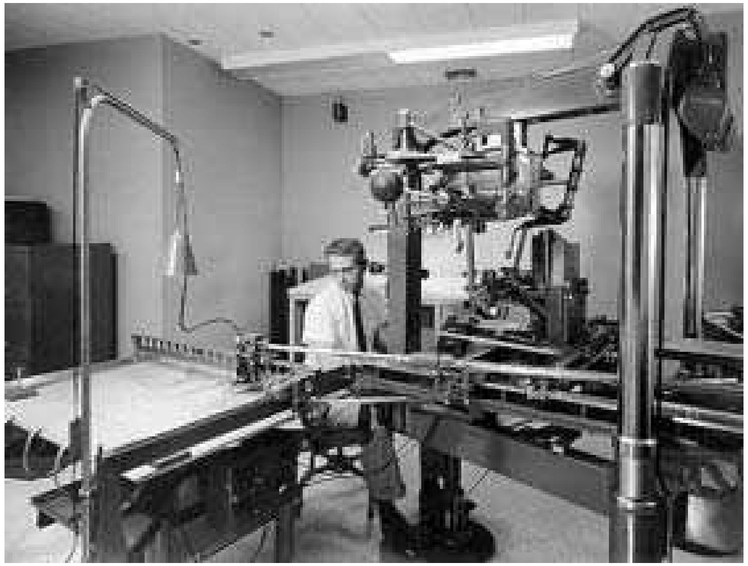
Nuremberg shears



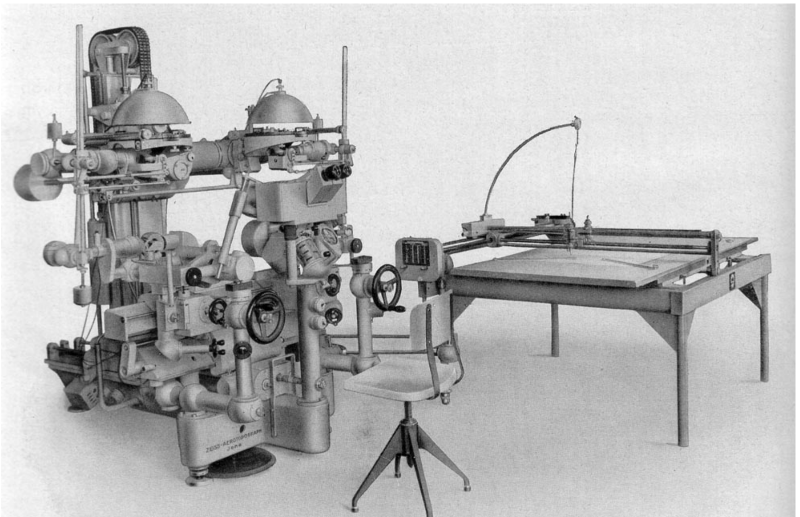
Principles of base determiantion – Zeiss parallelogram



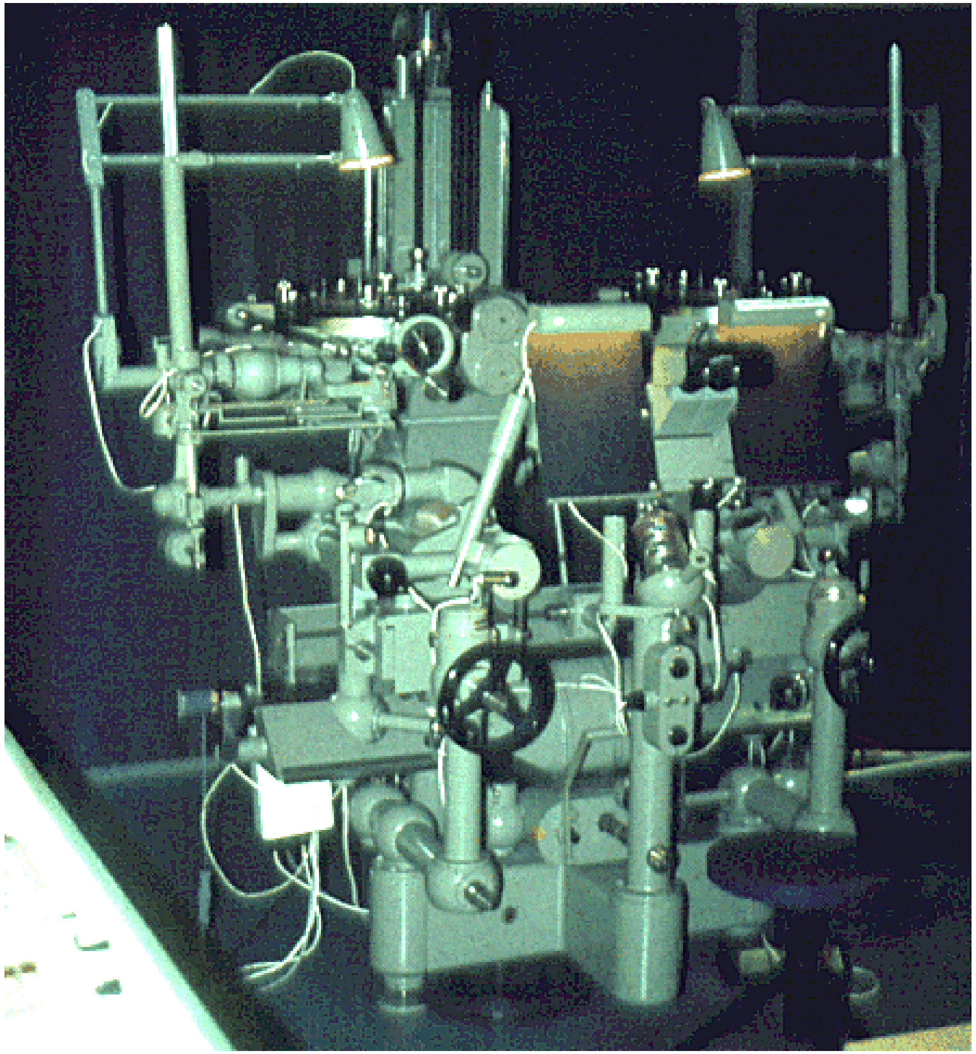
Stereoploters based on the mechanical principle



Galileo Santoni model IV

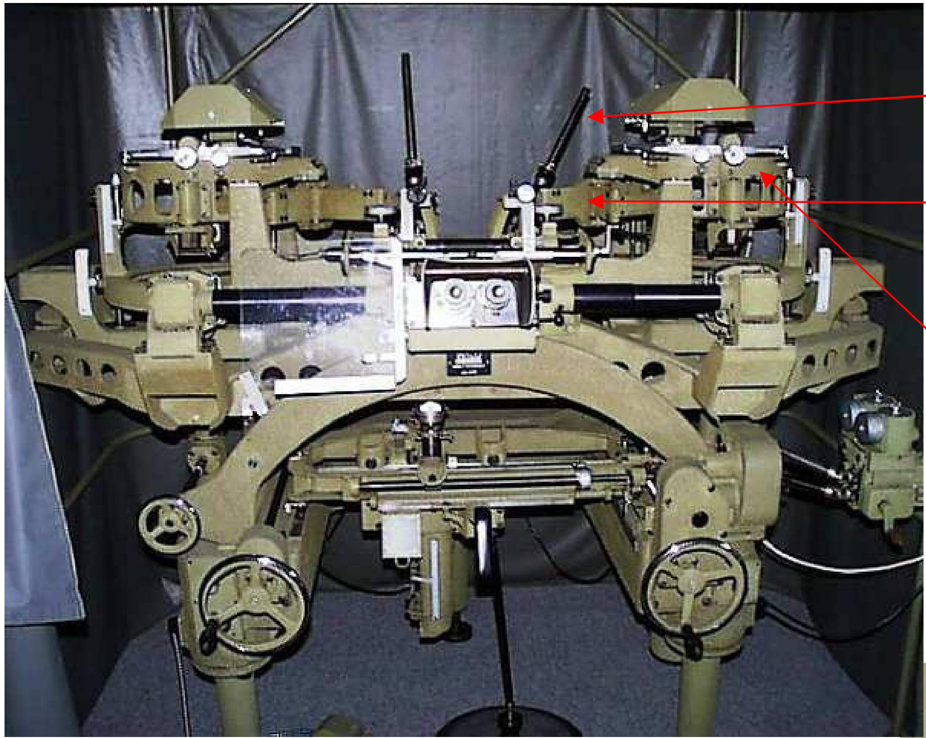


Stereoplanigraf Zeissa



Zeiss C5

Stereoploters based on the mechanical principle



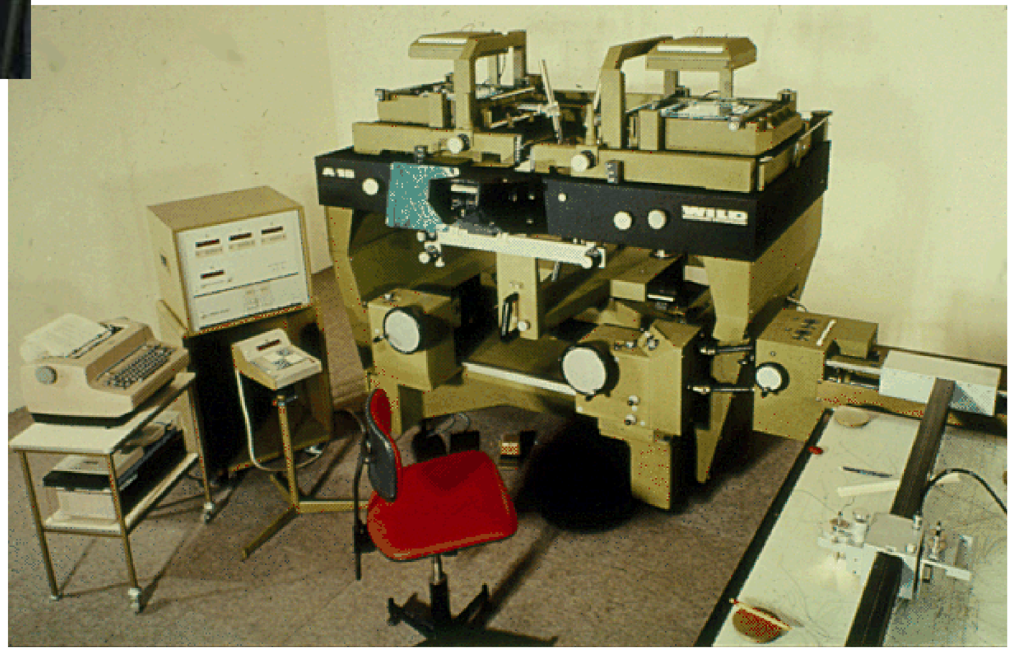
guides

Nuremberg shears

Wild A8

Camera carriers

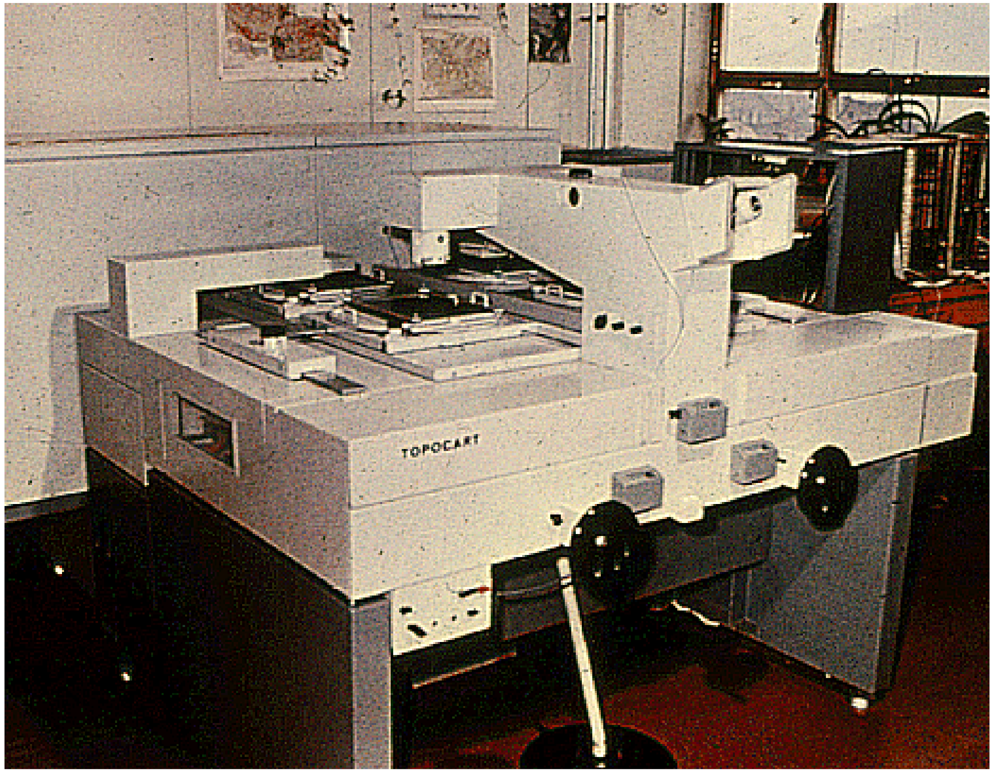
Wild A10



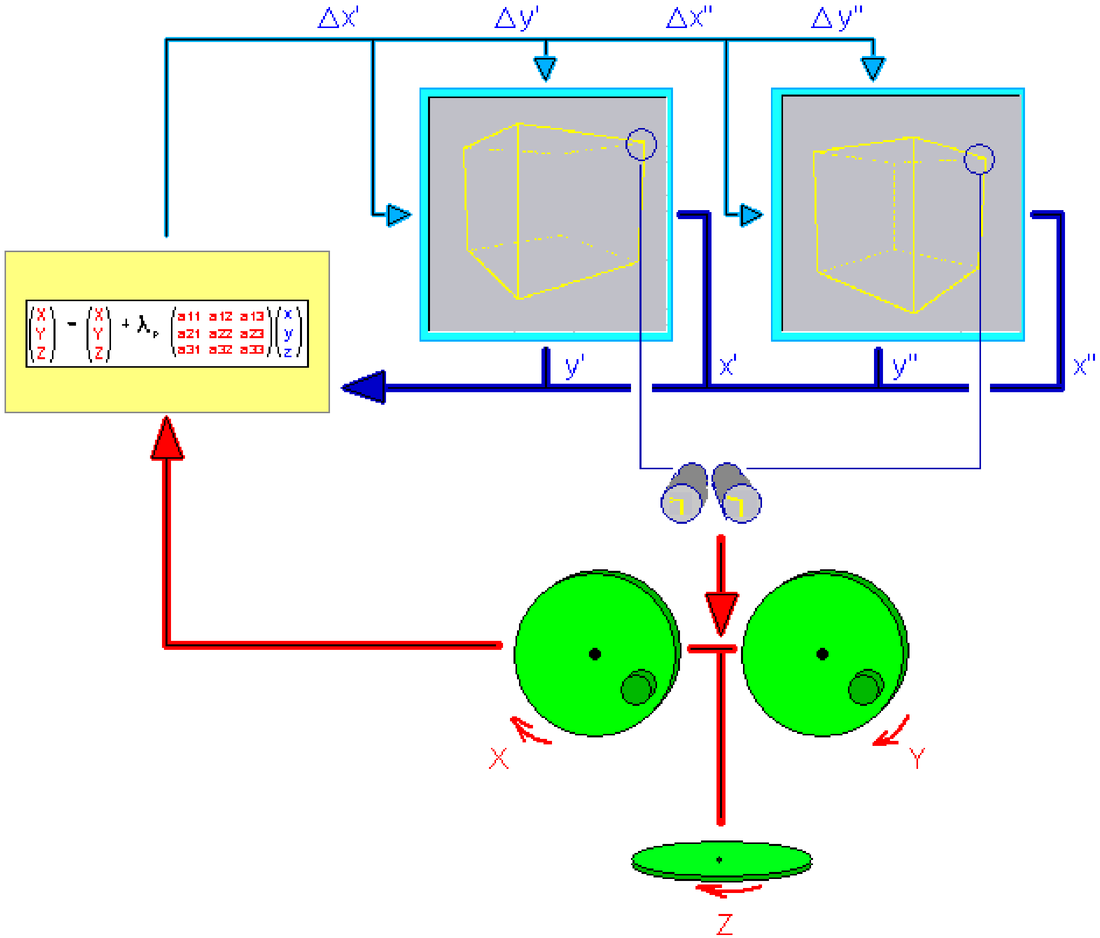
Stereoploters based on the mechanical principle

Kern PG-3

Topocart Zeissa



Analitycal stereoploters



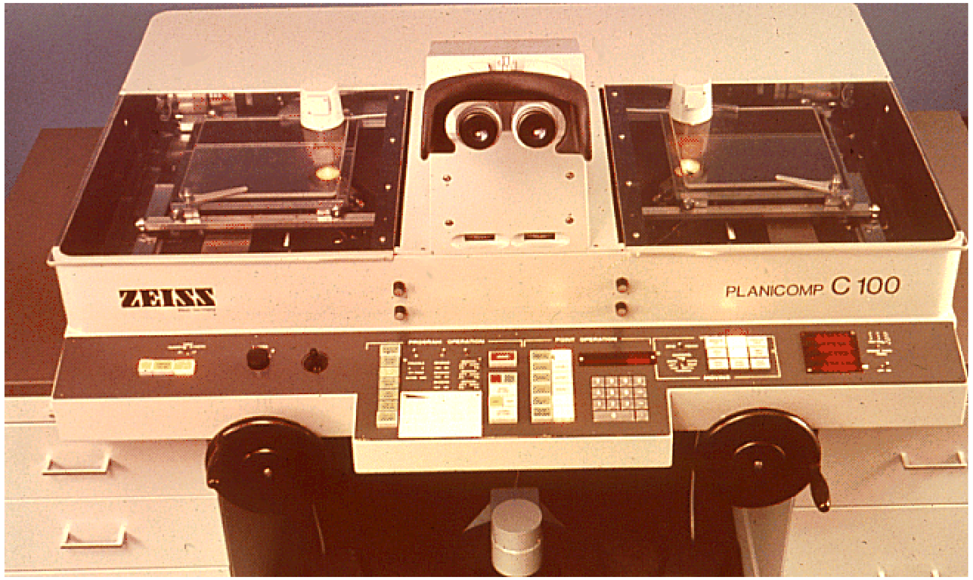
In analytical stereoploters images (diapositives) are placed on the horizontal carriers moving in relation to each other like in sterecomparator. After the measurements of the coordinates of photopoints for relative model orientation and calculation of the orientation, operator can using manipulators fix spatial model coordinates. Fiducial coordiantes area calculated live and allow to place the images in such way that we obtain stereoscopic effect. To the stereoploter a specific software is delivered for mapping and printing.

Steps of image processing using analytical stereploter

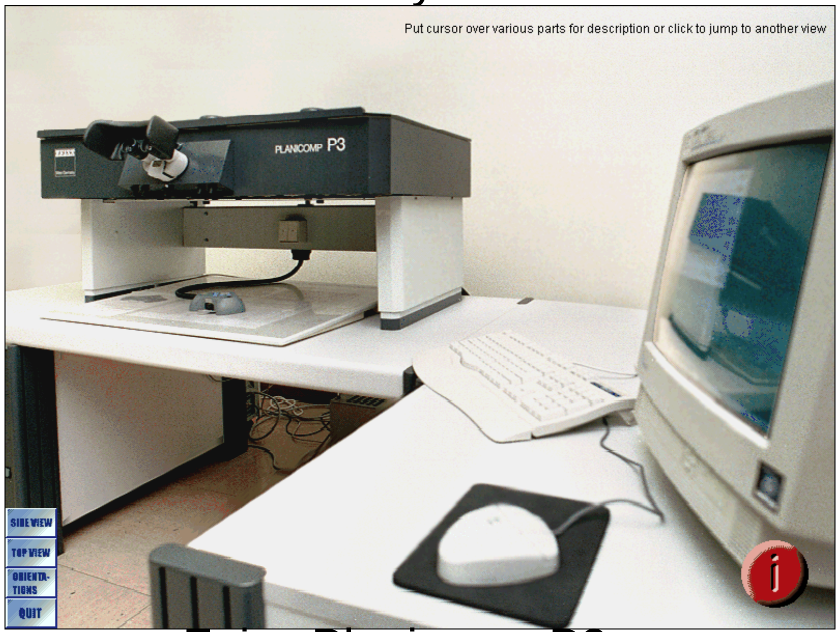
- Interior orientation – measurements of fiducial marks and transformation measured coordinates to the fiducial coordinates system (on the base of camera calibration)
- Relative orientation – lateral parallax elimination on the model in Gruber areas iteratively
- Absolute orientation – transformation of the model coordinate system to the object coordinate system
- Map digitization
- Measurements of the points for DTM creation
- Map edition

Analytical stereoploters

Wild Aviolyt AC3



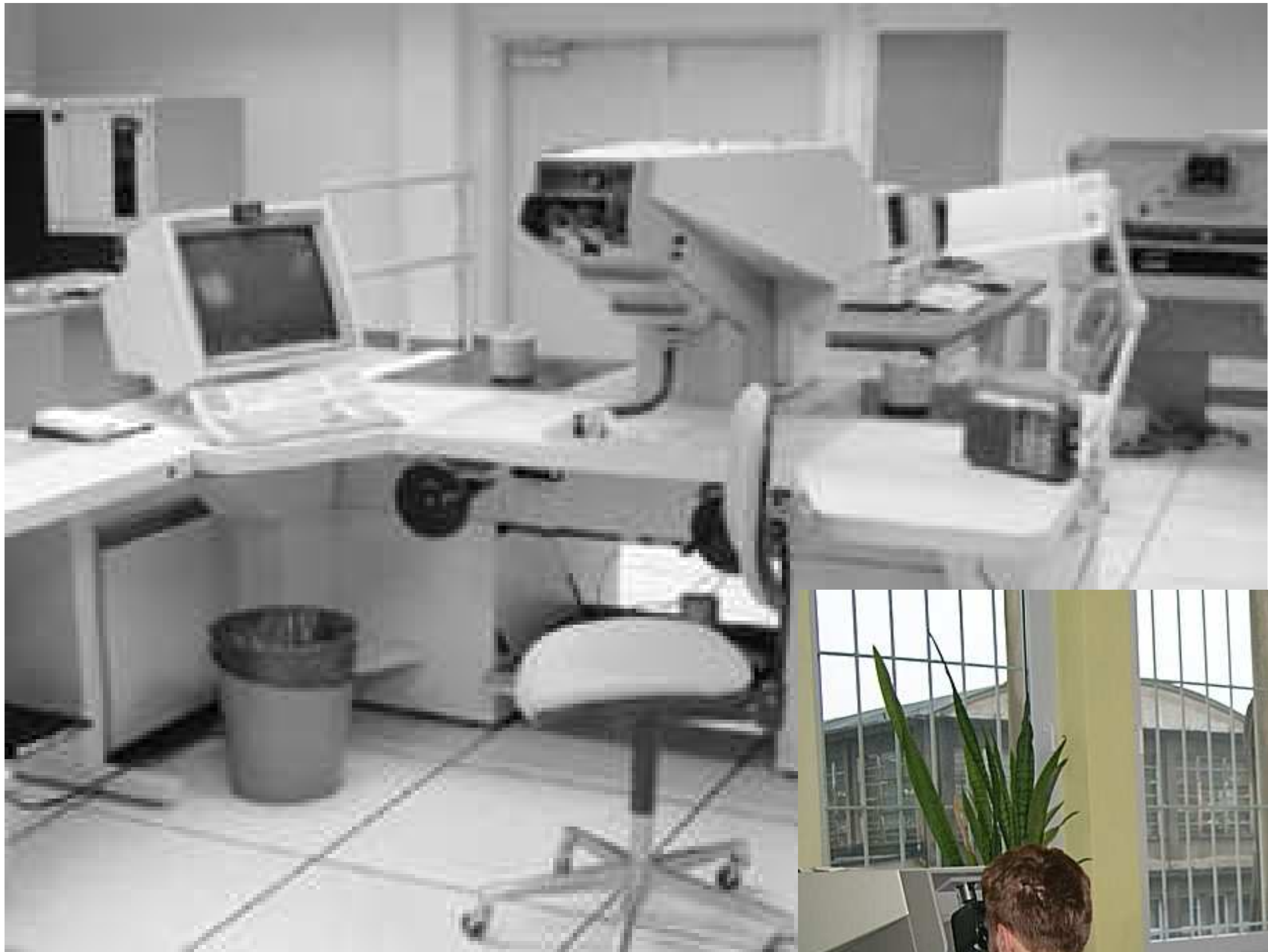
Zeiss Planicomp C100



Zeiss Planicomp P3

Matra Traster

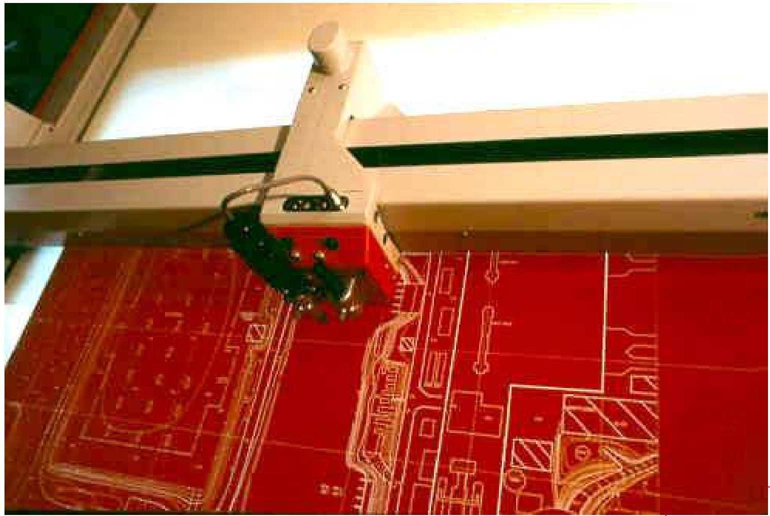
Analytical stereoploters



Intergraph IMA (InterMap Analytic)

ZGFiTŚ room 210

Products from analytical stereoploter



Plotter of analytical stereoploter

VSD-
AGH

Digital stereoploter

Image Station Intergraph

Summit

Steps of image processing using digital stereploter

- Interior orientation – measurements of fiducial marks and transformation measured coordinates to the fiducial coordinates system (on the base of camera calibration)
- Relative orientation – lateral parallax elimination on the model in Gruber areas iteratively
- Absolute orientation – transformation of the model coordinate system to the object coordinate system
- Map digitization
- Measurements of the points for DTM creation
- Map edition

Scope of photogrametric image station

- Source of images: scaning of the analogue airborne and terrestrial photos, airborne linear digital cameras, multispectral scanners, calibrated and un calibrated nonmetric cameras, panoramic cameras
- Image display: stereomodel, two images, many images simultaneously, 2D and 3D vectors, prospectives drawings, crossections and views, orthoimages, radar, lidar images
- Photogrammetric elaboration: interior, relative, absolute orientation, DLT, bundle adjustements „bundle method", aerotriangulation, camera calibration, photogrametric calculations as an option, orthorectification, manual and automatic measurenets for DTM creation, DTM creation (GRID, TIN), contour map
- Image processing: histogram, stretching, brightness, contrast, filtartion, epipolar image creation, mosaicing
- Vector map edition, CAD and GIS