Kinematic Measurement Systems
Summer Semester 2018

Lab 2 *(Team Laboratory)*
Group:___
Programming of Robot-Tachymeter

Date of first submission:

Date of renewed submission:

Date of issue	30.04.2019
Submission	14.05.2019

Number	First name	Last name	Student ID	Signature
1				
2				

Testat	1. control	Resubmission until	2. Control

1 Task

Kinematic measurements are performed in systems like Gauß-Krüger, UTM or local reference systems. This lab focuses on the computation of the position of the tachymeter and the determination of two new object points (N5, N6) by the use of the polar elements.

Please use your program from Lab 1 for further development.

The following steps and functions should be implemented in the program:

- Readout of the measurement data
- Reduction of slope distances
- Computation of local coordinates
- Transformation to global reference system using Helmert Transformation
- Determination of the coordinates for two new object points N5 and N6
- Data storage into file

2 Elaboration

- The labsheet must be submitted as hard copy.
- Each student of a particular group has to write a small report (in his own words) with description of the performed steps.
- A flow chart diagram of the written program has to be integrated in the elaboration.
- One program per group has to be submitted and uploaded to ILIAS.

3 Remarks

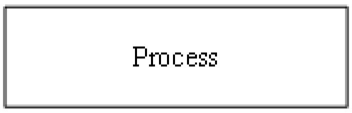
All formulas for the Helmert Transformation are attached.
Test your program with the given test data set (coordinates).
Weather correction and systematic errors like index error, horizontal axis error and visual error are already considered by the tachymeter.

4 Attachements

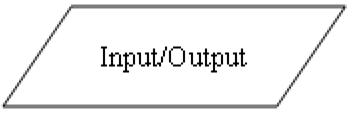
- Signs and symbols of flowchart diagram
- Test Data Set, Reference Coordinate Set of the measurement cellar
- Formulas for free stationing (Helmert Transformation)

Signs and symbols

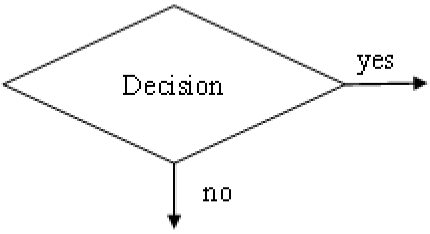
A terminal point – start, stop, halt, delay or interrupt



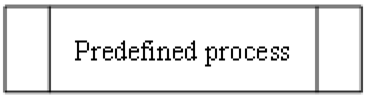
Any processing function; defined operations or location of information



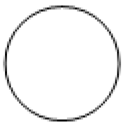
General i/o function; information available for processing (input), or recording of processed information (output)



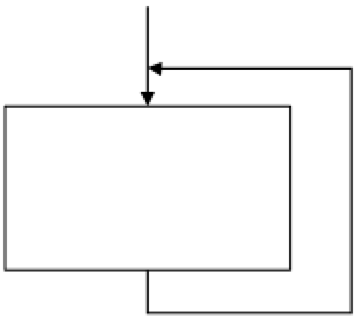
A decision or switching-type operation



Subroutine, function



Connector: Exit to, or entry from, another part of the chart



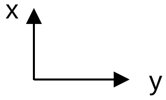
loop

Test Data Set (control points for Helmert Transformation):

Point ID	Local Coordinates		Global Coordinates	
	y	x	Y	X
Point 1	114.47	-21.05	17520.67	6410.71
Point 2	5.05	-52.53	17411.25	6379.23
Point 3	-148.03	3.59	17258.17	6435.35
Point 4	191.12	86.02	17597.32	6517.78
	Result		Position	
			17406.20	6431.76

Format example for the input data of the reference points:

ID	y	x
1001	465.233	65.356
1002	236.569	52.639

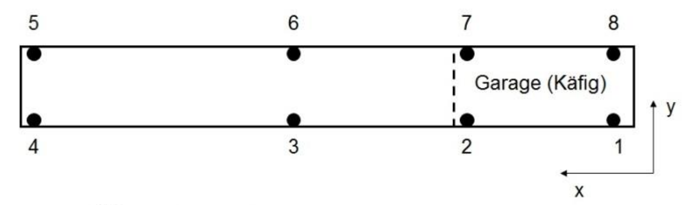


Equations for local coordinates:

$$D = \sin(V) \cdot S$$
$$y_{local} = \sin(Hz) \cdot D$$
$$x_{local} = \cos(Hz) \cdot D$$

$D\ldots$ horizontal distance
$V\ldots$ vertical angle
$S\ldots$ slope distance
$Hz\ldots$ horizontal angle

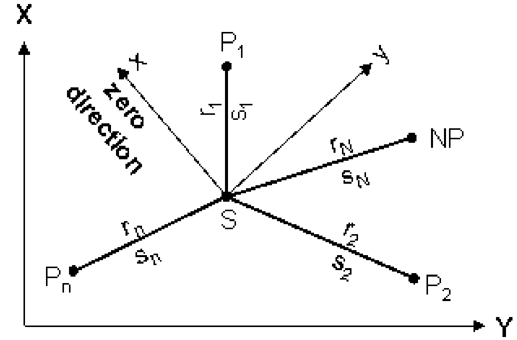
<u>Reference Coordinates Measurement Cellar (for the Test Session)</u>



Pkt	y	x
1	0.0000	0.0000
2	-0.0075	6.9552
3	-0.0163	21.7673
4	-0.0000	37.4980
5	2.9800	37.4794
6	2.9741	21.8653
7	2.9623	7.0614
8	2.9641	0.0459

Point ID	**Y**	**X**
N5		
N6		

Free Stationing (Helmert–Tranformation):



Transforming the polar elements (horizontal distance + horizontal angle) into (local) cartesian coordinates (y, x).

$\boxed{y_i = s_i \cdot \sin r_i}$ $\boxed{x_i = s_i \cdot \cos r_i}$ (P - R)

Positioning (coordinates of S)

Transforming the local coordinates (y, x) into the reference system (Y, X) by a helmert-transformation.

Coordinates of centroid

$$\boxed{y_S = \frac{[y_i]}{n} \qquad x_S = \frac{[x_i]}{n}} \qquad \boxed{Y_S = \frac{[Y_i]}{n} \qquad X_S = \frac{[X_i]}{n}}$$

Reduction to the centroid

$$\boxed{\bar{y}_i = y_i - \frac{[y_i]}{n} \qquad \bar{x}_i = x_i - \frac{[x_i]}{n}} \qquad \boxed{\bar{Y}_i = Y_i - \frac{[Y_i]}{n} \qquad \bar{X}_i = X_i - \frac{[X_i]}{n}}$$

n = number of identical points

Transformation parameters

$$\boxed{o = \frac{\left[\bar{x}_i \cdot \bar{Y}_i - \bar{y}_i \cdot \bar{X}_i\right]}{\left[\bar{x}_i^2 + \bar{y}_i^2\right]}} \qquad \boxed{a = \frac{\left[\bar{x}_i \cdot \bar{X}_i + \bar{y}_i \cdot \bar{Y}_i\right]}{\left[\bar{x}_i^2 + \bar{y}_i^2\right]}}$$

Coordinates of the station (S) (instrument site)

$$\boxed{Y_0 = Y_S - a \cdot y_S - o \cdot x_S} \qquad \boxed{X_0 = X_S - a \cdot x_S + o \cdot y_S}$$

Scale factor

$$\boxed{m = \sqrt{a^2 + o^2}} \qquad m = 1: \quad o = \frac{o}{m} \qquad a = \frac{a}{m}$$

Residuals

$$\boxed{v_{X_i} = -X_0 - a \cdot x_i + o \cdot y_i + X_i} \qquad \boxed{v_{Y_i} = -Y_0 - a \cdot y_i - o \cdot x_i + Y_i}$$

check: $\left[v_{Y_i}\right] = 0 \qquad \left[v_{X_i}\right] = 0$

Accuracy:

standard deviation of the coordinates

$$\boxed{s_X = s_Y = \sqrt{\frac{\left[v_{X_i} v_{X_i}\right] + \left[v_{Y_i} v_{Y_i}\right]}{2n - 4}}}$$

check: $\left[v_{X_i} v_{X_i}\right] + \left[v_{Y_i} v_{Y_i}\right] = \left[\bar{X}_i^2 + \bar{Y}_i^2\right] - \left(a^2 + o^2\right) \cdot \left[\bar{x}_i^2 + \bar{y}_i^2\right]$

Coordinates of the new points (NP)

Transforming of the measured polar elements into the local yx-System

$\boxed{y_N = s_N \cdot \sin r_N}$ $\boxed{x_N = s_N \cdot \cos r_N}$ (P - R)

Coordinates of the new points

$$\boxed{Y_N = Y_0 + a \cdot y_N + o \cdot x_N} \qquad \boxed{X_N = X_0 + a \cdot x_N - o \cdot y_N}$$

Correction of the coordinates – adjacency preserve integration.

Correction for each new point (regarding the deviation vector of all reference points against the distance from the station to the reference points).

$$\boxed{\begin{gathered} Y_N = Y_N + v_Y \\ v_Y = \frac{\left[p_i \cdot v_{Y_i}\right]}{[p_i]} \end{gathered}} \qquad \boxed{\begin{gathered} X_N = X_N + v_X \\ v_X = \frac{\left[p_i \cdot v_{X_i}\right]}{[p_i]} \end{gathered}}$$

$$p_i = \frac{1}{s_i} \qquad s_i = \sqrt{(Y_N - Y_i)^2 + (X_N - X_i)^2}$$

Setting out data of coordinates in the reference system YX

$$\boxed{a^T = \frac{a}{a^2 + o^2}} \qquad \boxed{o^T = -\frac{o}{a^2 + o^2}}$$

Source: Gruber, Joeckel: Formelsammlung für das Vermessungswesen (translation of Page 89/90)

$$y_0 = -X_0 \cdot o^T - Y_0 \cdot a^T$$

$$y_A = y_o + a^T \cdot Y_A + o^T \cdot X_A$$

$$x_0 = -X_0 \cdot a^T + Y_0 \cdot o^T$$

$$x_A = x_o + a^T \cdot X_A - o^T \cdot Y_A$$

Transforming the cartesian coordinates into polar elements **(R - P)**