Geomatics Engineering
International Master Program

Universität
Stuttgart

Geschwister-Scholl-Straße 24D, 70174 Stuttgart
Telefon: 0049 711 685 83388
Email: geoengine@geoengine.unistuttgart

Examination

Module 3 „Engineering Geodesy“

Winter 2016/2017

Module: **Engineering Geodesy**
Course: Monitoring
Course: Kinematic Measurement System

Examinor: Prof. Dr.-Ing. habil. V. Schwieger

Date: 24.02.2017

Time: 120 Minutes (08:00 – 10:00)

Remarks:

- Closed book
- Use of non-programmable and non-wireless-networking pocket calculators
- Please use a separate sheet for each task.
- Please write your name and matriculation number on each sheet.
- The exam is structured into two parts:
    - Part 1: Monitoring
    - Part 2: Kinematic Measurement Systems

Good luck !!!

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Course: Monitoring

Task 1: Bridge Monitoring System (13%)

Railway bridges may suffer from various kinds of damage such as fatigue and corrosion. In the German city Brandenburg, a new bridge monitoring system was installed in September 2016, in which geodetic sensors as well as geotechnical sensors were integrated.

Fig. 1: Railway bridge in Brandenburg, Germany (Source: https://www.drecoll.de/leistungen/geomonitoring/)

a) Please name three geodetic sensors and three geotechnical ones, respectively.

b) In modern monitoring technology, the hydrostatic leveling is quite commonly applied due to its various advantages. Please list 4 advantages and 2 disadvantages of this technology.

c) Stationary inclinometer chains that consist of several inclinometer transducers hanged in inclinometer tubing, in which the deformation exists, are also appropriate for long-term and automatic monitoring of endangered structures. Please give its typical accuracy.

d) In the inclination measurement lab (the lab 2), the tilt angle Δ of the tilting table was determined. Which geodetic instrument was applied to auto-collimation? Please explain why this should be done as the first step and in which step the tilt angle Δ was used.

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e) Comparing to the inclinometer that was used in the lab 2 to measure the inclination angles, extensometer was utilized to determine the height changes Δh caused by the deformation of the bending bar at 6 different sensor plate positions. Please describe and explain briefly how to calibrate the extensometer.

Task 2: Alignment and Measurement Concept (21%)

To monitor the deformations of the both railway lines on the bridge shown in Figure 1, a survey company has decided to utilize the optical alignment as the measurement method. As shown in Table 1, the horizontal direction r_i^0 and r_i^1 for target 1 – 6 were measured at epoch 0 (reference, without deformation) and at epoch 1 (with deformation) using the same alignment instrument Leica TM5000 $(i = 1,2,\dots,6)$, respectively.

Table 1: Measured horizontal direction with the same alignment instrument at epoch 0 (without deformation) and at epoch 1 (with deformation), respectively

	measured horizontal angle epoch 0 r_i^0 [gon]	measured horizontal angle epoch 1 r_i^1 [gon]
target 1	0.0000	399.9979
target 2	0.0000	0.0011
target 3	0.0000	399.9996
target 4	0.0000	0.0018
target 5	0.0000	0.0014
target 6	0.0000	0.0013

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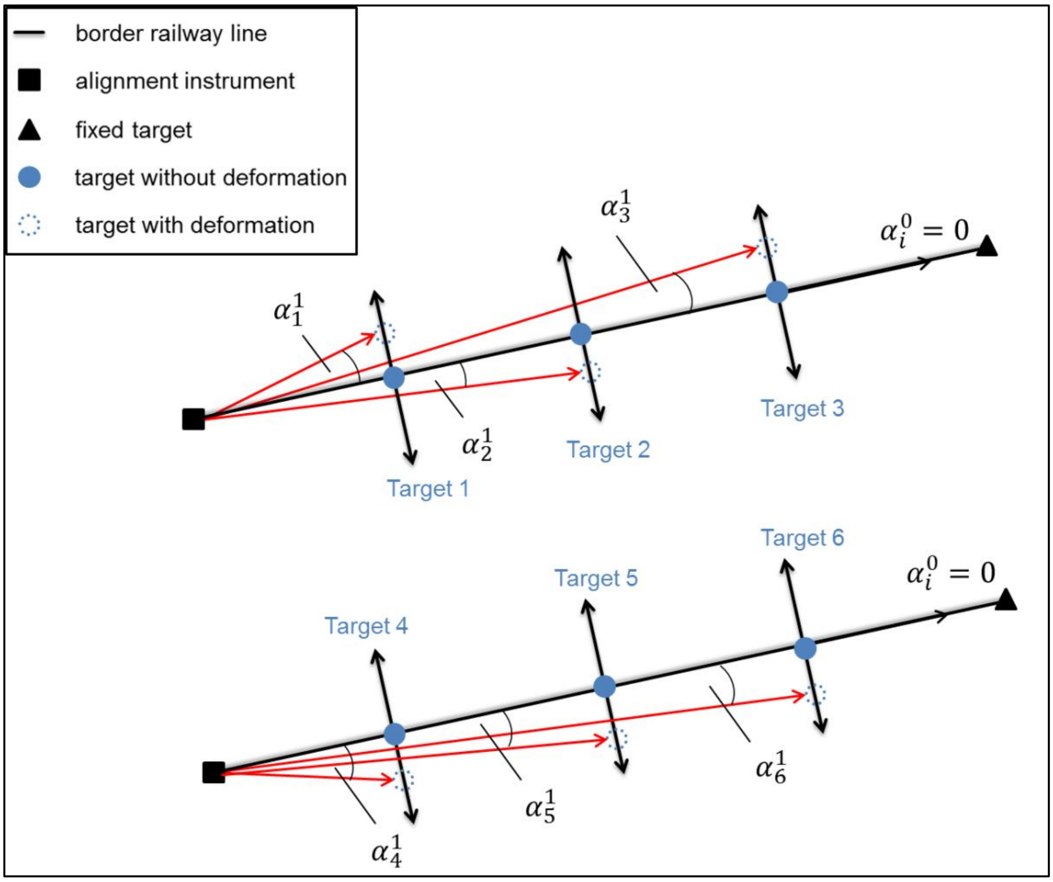

Fig. 2: Geometric situation related to alignment measurement of the left and right (border) railway line

a) Please calculate the angles of the deformations α_1^1 to α_6^1 at the targets 1 to 6 using the horizontal direction measurements of epoch 0 and epoch 1 in Table 1.

b) Please determine the cross deviation q at the target 1 as well as its standard deviation σ_q using the following formulas. The horizontal distance between the alignment instrument and the target 1 is assumed to be 20 m with an empirical variance $\sigma_s^2 = 1.44\,\text{mm}^2$ and the empirical standard deviation of the horizontal direction measurement is equal to 0.7 mgon.

$$q = s \cdot \sin(\alpha_i^1 - \alpha_i^0), \qquad \sigma_q^2 = \left(\frac{\partial q}{\partial s}\right)^2 \cdot \sigma_s^2 + \left(\frac{\partial q}{\partial \alpha_i^1}\right)^2 \cdot \sigma_{\alpha_i^1}^2 + \left(\frac{\partial q}{\partial \alpha_i^0}\right)^2 \cdot \sigma_{\alpha_i^0}^2$$

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c) Please design a measurement concept for this bridge monitoring project. The movement information of the border railway lines is given as follows.

Period of deformation	Expected movement
daily (24 h)	$\Delta x = 3.6\ mm$
annually (365 d)	$\Delta x = 8.8\ mm$

c.1) Please name the measurement quantity.

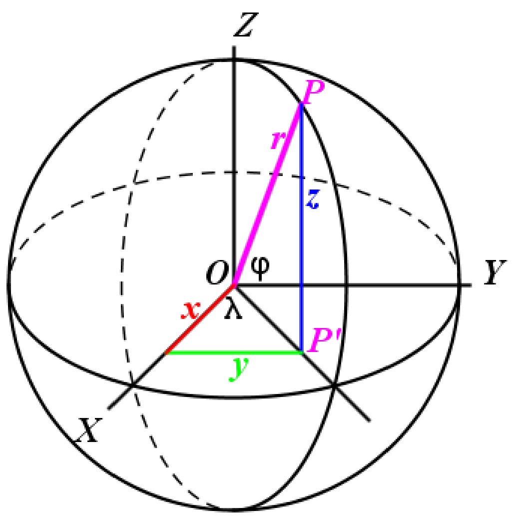
c.2) What kind of reference system would you like to choose?

c.3) Please determine the measurement interval

c.4) Please give the minimum sampling rate

Task 3: Deformation Analysis (16%)

As illustrated in Figure 3, the spherical coordinates (λ, φ) can be transformed into the Cartesian coordinates (*x*, *y*, *z*) using the formulas below assuming that the Earth's radius is given as $R = 6371$ km.



$$x = R\cos\varphi\cos\lambda,$$
$$y = R\cos\varphi\sin\lambda,$$
$$z = R\sin\varphi.$$

Fig. 3: Relationship between the cartesian coordinates (*x*, *y*, *z*) and the spherical coordinates (λ, φ) of an arbitrary point *P*

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a) Please list the 4 deformation models as well as the information about geometry, time-dependence and influencing forces in a table.

b) For long-term monitoring of the railway lines, high-precision GNSS receivers were used to determine the position coordinates of the targets 1 to 6 (see Figure 2). The target 2 should be tested for movements using the following information. Please transform its geographic coordinates (latitude φ and longitude λ) into the cartesian coordinates (x, y, z) using the formulas above and perform a test for localization of coordinate movements.

<u>geographic coordinates of the target 2 at epoch 0 and at epoch 1, respectively:</u>

Latitude φ^0 : 48°46'56.69"

Longitude λ^0 : 9°10'37.77"

Latitude φ^1 : 48°46'56.69"

Longitude λ^1 : 9°10'37.76"

<u>covariance matrix of deformations in Millimeter:</u>

$$\Sigma_{dd} = \begin{pmatrix} s_{dx} \\ s_{dy} \\ s_{dz} \end{pmatrix} = s_0^2 \cdot \begin{pmatrix} 2.25 & 0 & 0 \\ 0 & 1.96 & 0 \\ 0 & 0 & 6.25 \end{pmatrix} \text{mm}^2, \text{ where } s_0^2 = 1.$$

Confidence level: 98%

Degree of freedom: $f = 1000$

t-distribution-quantile (extracted from table): $t_{1000,0.98}$ = 2.33

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Course: Kinematic Measurement Systems

Task 1: Definitions (8%)

a) Multisensor systems can be divided into 3 general classes. Please name the 3 classes, give a short description on their characteristic and name one application example for each class.

b) The dynamic model may be used for kinematic objects. Please give a definition on this specific model.

Task 2: Robot Tachymeter (10%)

a) Please name 6 sensors within a robot tachymeter.

b) Kinematic measurements with a robot tachymeter are affected by time delay and synchronization errors. Please describe the two errors and their negative effects on the measurements and give a related sketch.

c) Which countermeasures can be taken to minimize, respectively suppress the synchronization error? Please give a sketch.

Task 3: Further Kinematic Sensors (12%)

a) Please name 4 further kinematic sensors and give their measurement quantities and accuracy ranges.

b) Please give one sensor combination, which can be used to establish a 2-D grader control for height and slope. Please give an argument for your decision.

c) Please name 6 error sources of GNSS.

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Task 4: Modeling of Moving Objects (8%)

a) In Kalman Filters, the prediction of the system state is one of the main steps. Please give the formula for the prediction step of the variance propagation within the Kalman Filter and identify the following matrices:

- Covariance matrix of the state vector (1)
- Covariance matrix of the influencing forces (2)
- Covariance matrix of the disturbance vector (3)

b) You have to choose a suitable construction machine for a new construction site. The requirement from the contractor is as follows: the maximum radii during the vehicle's operation must not exceed 6 meter. You decide to operate a tracked vehicle. Which gauge the vehicle must have for the given velocities? Use the following information:

Incept theorem: $R \cdot (v_r - v_l) = -\frac{B}{2} \cdot (v_r + v_l)$

$v_r = 2.5 \frac{m}{s}$ *Velocity right track*

$v_l = 3.5 \frac{m}{s}$ *Velocity left track*

B *Gauge*

Task 5: Control of Moving Objects (6%)

a) Please give a sketch of a controlled system with compensation. Identify and the following variables: delay time and rise time.

b) Please identify the controllability of a specific system by the use of following values: $delay\ time = 165\ ms$, $rise\ time = 490\ ms$

Task 6: Classification of Guidance Systems (6%)

a) Please name the 3 different systems according to their degree of automation and give an example for each level on the field of construction machines.