S2 – Modeling and Analysis

Content

- This document is a high-level curriculum design which captures the principles, competencies, learning outcomes and syllabus items proposed for the updated curriculum specific to S2 – "Modeling and Analysis.

S2: MODELING AND ANALYSIS

LEARNING OBJECTIVES

- **Establish the fundamental knowledge of modeling and analysis required in surveying**
- **Support subsequent learning**

Key Principle	Motivation	Syllabus Items	Competencies and Learning Outcomes
MODELING AND PREDICTION	Surveyors must know how to use modeling and prediction to derive useful information from measurements	• Fundamentals of spatial data analysis; visualise, explore and then model • Conditional, parametric, and general models • Least squares adjustment models for different geomatics observables (distance, azimuth, direction, etc.) • Modeling of time series • Simple prediction model as a component of Kalman filtering • Sequential adjustment model • Manipulation of normal equations in adjustments	**Competencies** • Describe the different types of models, their characteristics, and how to derive them • Justify the selection of models of survey measurements **Learning Outcomes** • Formulate models for ellipsoidal, spherical, and conformal mapping plane representations of the earth • Derive least squares adjustment models (conditional, parametric, and general) for geomatics problems, such as levelling, traverse, triangulation and trilateration networks • Transform coordinates from local system to real world coordinate system, such as UTM, and use the transformation as prediction model • Model time and spatial data series for further analysis, e.g. for deformation analysis, etc.

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ESTIMATION AND APPROXIMATION	Surveyors must be able to quantitatively evaluate parameters or functions from measurements that have random component	● Overdetermined system of equations ● Datum problems, including datum transformation ● Adjustment calculus principle ● Principles and properties of least squares estimation ● Least squares approximation ● Calculus as applied to linearize non-linear systems of equations ● Matrix manipulation involved in estimation and approximation	**Competencies** ● Describe the least squares estimation principles, properties, and steps, from model formulation to solution stage ● Construct curves or mathematical functions, which best fit to series of data points ● Evaluate the impacts of different variables (human, instrumental, atmospheric conditions, ground instability, etc.) on measurements relating to equipment calibration, etc. ● Perform pre-analysis and applying statistical analysis. **Learning Outcomes** ● Apply matrix theory in estimation and approximation problems ● Apply least squares adjustment principle to solve geomatics problems (compute the parameter vector and its variance-covariance matrix), such as levelling, traverse, triangulation and trilateration networks ● Perform partitioned least squares adjustments to eliminate nuisance parameters from measurements

			• Apply error propagation approach to determine quality of approximated functions and estimated parameters • Solve over-constrained and free network (including inner-constrained) adjustment problems • Analyze systematic and random errors in measurements and equipment, and their impacts on estimated parameters, such as in equipment calibration • Apply regression analysis to geomatics problems, such as equipment calibration and time series

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FILTERING	Surveyors must be able to screen (filter) out unwanted variations in signal to account for major variations in the signal	• Spectral analysis of time series • Relationship between sequential least squares adjustments and filtering • Relationship between spectral analysis of time series and filtering • Finite Impulse Response (FIR) filter design methods in image processing	**Competencies** • Perform spectral analysis • Design and use various filters • Describe the relationship between spectral analysis and filtering • Describe the relationship between sequential least squares adjustment and filtering • Describe the principles of a Kalman filter

		• Other filtering algorithms, such as used in positioning problems, e.g. Kalman filtering	**Learning Outcomes** • Perform spectral analysis of a signal • Identify the spectral components of a signal to be filtered/retained • Design and use various FIR filters (lowpass, highpass, bandpass, derivative, etc.) for a problem

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STATISTICAL DATA ANALYSIS	Surveyors must be able to organize, interpret and evaluate survey measurements and the parameters based on those measurements	• Error propagation law and pre-analysis of geomatics networks • Probability and statistics to assess quality of geomatics measurements • Probability and statistics to assess quality of adjustment solutions	**Competencies** • Describe the different types of errors and their characteristics, including how they are propagated • Apply the law of random error propagation to determine variance-covariance matrices of measurements and adjusted quantities • Construct confidence regions for measurements • Organize, interpret and statistically evaluate survey measurements and the possible estimated parameters **Learning Outcomes**

			• Apply law of random error propagation to levelling and traverse tasks and similar problems to predict misclosure errors based on the precision of the instruments to be used and the precision of the control network(s) • Conduct network design and pre-analysis for GNSS and traditional surveys by following appropriate specifications and guidelines • Compute and analyze redundancy (and absorption) numbers, internal reliability and external reliability of geodetic network • Estimate the variance factor of an adjustment and evaluate its quality, e.g. in blunder (outlier) detection • Perform statistical hypothesis tests on mean and variance to detect and identify outliers (blunders) in observations • Perform statistical hypothesis tests using appropriate distributions (normal, Chi-square, Student's t, F statistics, and Pope's tau) • Compute and analyze variance components • Estimate residuals of an adjustment (including histogram plot) and statistically analyse them for possible outlier • Apply the concepts of confidence intervals and absolute and relative error ellipses to express quality of surveys • Determine and evaluate local, network, internal and external accuracies of surveys • Determine the confidence level and error probability of statistical decisions (with appropriate definitions of significance level, power of test, type I and type II errors)