

## Exam questions for course „Advanced mathematics in Geodesy and Surveying” in 2022.

1. Describe Singular Value Decomposition (SVD), its characteristics, and mention some of its applications. What is the spectrum of a matrix? Outline the main idea of Principal Component Analysis (PCA) and its connection with SVD.
2. Describe the basic principle and algorithm of Kalman filtering, demonstrate its application with an example. What is the connection between Kalman filtering and adjustment in groups? How it can be derived from a conditional density?
3. Introduce the main principle, basic formulas and and problems of extended Kalman filtering (EKF). How are these problems addressed with unscented Kalman filter (UKF)? What is the basic priciple of the unscented transform?
4. Describe principle and main steps of iterative RANSAC parameter estimation. What algorithms are required within RANSAC to solve a particular parameter estimation problem? How the sphere fitting problem is solved with RANSAC? What are the different flavors of RANSAC?
5. Introduce main characteristics of continuous (CFT) and discrete Fourier Transforms (DFT) and their relationship. Describe Nyquist-Shannon theorem, spectral aliasing and leakage. Main idea of the fast Fourier transform (FFT) and some of its applications.
6. Describe principle of the continuous wavelet transform (CWT). Normalization of the wavelet spectrum, significance testing and cone of influence. Filtering by continuous wavelet transform.
7. Discrete (orthogonal) wavelet transform (DWT) and its connection with quadrature mirror filters (QMF). Introduce discrete Haar transform and principle of multiresolution analysis (MRA). How DWT can be applied for data compression and solution of a large system of linear equations?
8. Summarize basics of random processes, characteristics of digital filters, finite impulse response (FIR) and recursive (IIR) filters. What are the zeros and poles of a digital filter? How digital filters can be characterized with the z-transform?
9. Definition of power spectral density (PSD) and its main characteristics for a continuous random process. How to determine the PSD of a filtered signal? PSD estimation of discrete random processes, periodogram estimation and its drawbacks and how to fix them. Parametric and nonparametric PSD estimation methods.
10. What are the main architectures of Neural Networks? How do artificial neurons work? What common activation functions are used? How to train a neural network? What is backpropagation and stochastic gradient descent? What is the architecture of a Kohonen map and how to update its weights? What is the basic architecture of Convolutional Neural Networks and what applications do they have? Why Recurrent Neural Networks are useful?
11. Most Frequent Value procedures of statistical estimation. Why do we need to care about the fact that our data densities in practice are only exceptionally Gaussian (or normal)? What is statistical efficiency, robustness and resistance? How to calculate the most frequent value of a dataset? What is the maximum likelihood estimate of the location parameter of a dataset with Cauchy PDF (probability density function)?
12. What is a lattice and how it can be characterised with a basis? What are the fundamental paralelotope and lattice determinant? What is a lattice reduction and why is it useful? What are the two conditions for the LLL (Lenstra-Lenstra-Lovász) lattice reduction. What applications LLL has? What problem is solved by the integer least squares (ILS) method and how it is used in GNSS processing? How lattice reduction can be used for the phase unwrapping problem?