DATA AND INFORMATION PROCESSING

Earth Science Engineering MSc

2022/2023 1. semester

COURSE COMMUNICATION DOCUMENT

University of Miskolc
Faculty of Earth Science and Engineering
Institute of Geophysics and Geoinformatics

Course datasheet

Course title: Data and information processing **Responsible instructor** (name, position, scientific degree): Dr. Armand Abordán, assistant professor Dr. Endre Nádasi, assistant lecturer	**Neptun code:** MFGFT7100031 **Responsible department/institute:** Institute of Geophysics and Geoinformation Science / Department of Geophysics **Type of course: C**
Position in Curriculum (which semester): 2	**Pre-requisites:** none
Number of Contact Hours per Week (lec.+prac.): 2+1	**Type of Assessment (examination / practical mark / other):** practical mark
Credits: 4	**Course:** full-time **Program:** Earth Science Engineering MSc

Course Description:
Understanding the basics of inversion method-based geoinformation processing for Earth Scince Engineers.

Competencies to evolve:

Knowledge*:* T1, T2, T3, T6, T9

Ability*:* K2, K6, K7

Attitude*:* A1, A2, A3, A4, A5, A7

Autonomy and responsibility*:* F1, F2, F3, F4, F5

The short curriculum of the subject:
Introduction to the vector analysis. Multidimensional Euclidean spaces: N-dimensional dataspace, M-dimensional model parameter space. The parameters of inversion-based data and information processing. Classification of geophysical problems: direct problem, inverse problem. Explicit and implicit forms of direct problems. The linearization of the nonlinear direct problems, introduction of the Jacobi-matrix. The linear inverse problems. Solution of the overdetermined linear inverse problems: Gaussian Least Squares method (LSQ). Normal equation, stability, condition number. Definition of the generalized linear inverse problem. Solution of the underdetermined linear inverse problem by Lagrange multiplicators, generalized inverse problem. The principle of the simple solution. The principles of information theory. The theory of signals. The principles of data and information processing by means of inversion methods. Modeling, model types. Theoretical and measured characteristics. Error characteristic parameters in the data and the model space. The purport of local and global inversion methods. Spectral transformations (Fourier integral transformation, DFT, FFT, Z-transformation). Convolution, discrete convolution. Correlation functions, discrete correlation functions. Deterministic filtering. Image processing filters.

Assessment and grading: Attendance at lectures is regulated by the university code of education and examination. Writing two tests at least satisfactory level, respectively during the semester is the requirement of signature.

Exam grading scale: unsatisfactory (0-45%), satisfactory (46-60%), medium (61-70%), good (71-85%), excellent (86-100%).

The 3-5 most important compulsory, or recommended literature (textbook, book) resources:

1 Dobróka M., 2001: The Methods of Geophysical Inversion. University textbook, University of Miskolc.

2. W. Menke, 1984: Geophysical Data Analysis: Discrete Inverse Theory. Academic Press Inc.

3. Mrinal Sen and Paul L. Stoffa: Seismic Exploration - Global Optimization: Methods In Geophysical Inversion. Software, Elsevier Science Ltd. 1997.

4. Szabó N.P., Dobróka M.: Float-encoded genetic algorithm used for the inversion processing of well-logging data Global Optimization: Theory, Developments and Applications: Mathematics Research Developments, Computational Mathematics and Analysis Series. New York: Nova Science Publishers Inc., 2013. pp. 79-104.

6. P.J.M. van Laarhoven, E.H.L. Aarts, 1987: Simulated Annealing: Theory and Applications. D. Reidel Publishing Company, ISBN 90-277-2513-6

Syllabus of the semester

Week	Lecture
September 6.	Introduction to the vector analysis.
September 13.	Multidimensional Euclidean spaces: N-dimensional dataspace, M-dimensional model parameter space.
September 20.	The parameters of inversion-based data and information processing.
September 27.	Classification of geophysical problems: direct problems, inverse problems. Explicit and implicit forms of direct problems.
October 4.	The linearization of the nonlinear direct problem, introduction of the Jacobi-matrix.
October 11.	The linear inverse problem.
October 18.	1st mid-term test. Solution of the overdetermined linear inverse problems: Gaussian Least Squares method (LSQ).
October 25.	Normal equation, stability, condition number.
November 1.	No education.
November 8.	Definition of the generalized linear inverse problem.
November 15.	Solution of the underdetermined linear inverse problem by Lagrange multiplicators.
November 22.	The generalized inverse problem.
November 29.	2nd mid-term test. The principle of the simple solution.
December 6.	Repeated midterm tests. Applications of geophysical inversion.

Week	Lectures and seminars of Spectral Data and Information Processing
September 6.	Starting test. Basis of information theory. Signal theory.
September 13.	Discretization. Errors of discretization.
September 20.	A/D conversion. A/D converters.
September 27.	Fourier-transform. Discrete Fourier Transform (DFT).
October 4.	Fast Fourier Transform. Z-transform. Spectrum calculation using Z-transformation.
October 11.	Convolution. Discrete convolution.
October 18.	1st written midterm exam.
October 25.	Correlation functions (auto- and cross-correlation function).
November 1.	No education.
November 8.	Discrete correlation functions (discrete auto- and cross-correlation function).
November 15.	Basis of deterministic and stochastic filtering.
November 22.	Image processing.
November 29.	2nd written midterm exam.
December 6.	Semester closing.

Midterm practical exams from the Spectral Data and Information Processing:

xx.xx.201x, Miskolc

Data and Information Processing I. **1st midterm practical exam, A**

(Solution time: 50 minutes)

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Name with Neptun code

1. Draw up the error vector of discretization in a complex plan when there is an angle of 60 degrees between the error vector and horizontal axis (10 points).

2. Give the sampling error in percent when sampling number is $\boldsymbol{5 \cdot 10^3}$ (10 points).

3. Give the conversion error (amplitude resolution error) of ***10*** bits A / D converter in percent (10 points).

4. Derive dimension right Inverz DFT formula (8 points) and index right Inverz DFT formula (4 points) from analytic Fourier-transform.

5. Calculate and give the type of following filter (10 points).

$$\{w_n\} = \left(-1, \overset{\downarrow}{2}, -1, 1 \right), \quad \Delta t = 0.5 \text{ sec}.$$

6. Calculate the ***6*** bits digital code of ***651 mV*** in ***0 mV*** and ***1024 mV*** signal interval (24 points).

7. Calculate the complex spectrum - F(f) - of the following discrete data series using Z-transformation and give real spectra – Re(f), Im(f), A(f) and Φ(f) - of the complex spectrum (24 points).

$$\left[\overset{\downarrow}{1}, -1, 2, 1, -2 \right], \quad \Delta t = 2 \text{ sec}, \quad f = 0{,}125 \text{ Hz}.$$

Result:	80.5-100.0 points:	A1 level (5),
	70.5-80.0 points:	A2 level (4.5),
	60.5-70.0 points:	B level (4),
	50.5-60.0 points:	C level (3.5),
	40.5-50.0 points:	D level (3),
	30.5-40.0 points:	E1 level (2.5),
	20.5-30.0 points:	E2 level (2),
	0.0-20.0 points:	F level (1).

<u>Solution</u>: tasks are solved in seminars.

xx.xx.201x, Miskolc

Data and Information Processing I. **2nd practical exam**

Engineering in Technical Earth Science MSc. *(Solution time: 75 minutes)*

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Name with Neptun code

1. Given the following time series: $\Delta t = 0.5\ sec$,

$$\{x_n\} = (\overset{\downarrow}{1},-1,1,2,-2), \qquad \{y_n\} = (\overset{\downarrow}{1},-2,2,2,-1).$$

1.a., Calculate the discrete corrected cross-correlation function $\{R_{xy}(k)\} = (R_{-3}, R_{-2}, R_{-1}, R_0, R_1, R_2, R_3)$, and illustrate the result in figure using Dirac pulse sequence (24 points).

1.b., Calculate the discrete corrected autocorrelation function: $\{R_{xx}(k)\} = (R_{-3}, R_{-2}, R_{-1}, R_0, R_1, R_2, R_3)$, and illustrate the result in figure using Dirac pulse sequence (16 points).

2. Derive the dimension right discrete cross-correlation formula (6 points) and index right discrete cross-correlation formula (4 points) from analytic cross-correlation.

3. Given the following discrete time series: $\Delta t = 2\ sec$,

$$\{x_n\} = (\overset{\downarrow}{2},1,-2,1,0,2,-1,2), \qquad \{w_n\} = \left(1,-1,\overset{\downarrow}{3},-2\right)$$

Determine the values of discrete convolution $\{x_n\} * \{w_n\}$ and the draw the functions w_n, x_n and y_n in figure using Dirac pulse sequence (30 points).

4. Calculate and give the type of following filter (10 points).

$$\{w_n\} = \left(2,-2,\overset{\downarrow}{4},-1,1\right), \qquad \Delta t = 0.5\ sec.$$

7. Give and draw up the $A(f)$ spectrum of transmission characteristics ($W(f)$) of an ideal bandpass filter (10 points).

Result:	80.5-100.0 points:	A1 level (5),
	70.5-80.0 points:	A2 level (4.5),
	60.5-70.0 points:	B level (4),
	50.5-60.0 points:	C level (3.5),
	40.5-50.0 points:	D level (3),
	30.5-40.0 points:	E1 level (2.5),
	20.5-30.0 points:	E2 level (2),
	0.0-20.0 points:	F level (1).

<u>Solution</u>: tasks are solved in seminars.

Sample for the exam

Please, describe the basics of LSQ method, deduce the normal equation. Please, determine the condition number of normal equation's matrix.

The solution can be found in the university text book „The methods of geophysical inversion".