GEOPHYSICAL INVERSION

Earth Science Engineering MSc / Geophysical Engineering specialization

2023/2024 Second Semester

COURSE COMMUNICATION FOLDER

University of Miskolc
Faculty of Earth and Environmental Sciences and Engineering
Institute of Exploration Geosciences

Course datasheet

Course Title: Geophysical inversion **Responsible instructor** (name, position, scientific degree)**:** Norbert Péter Szabó Prof. Dr., Ph.D., dr. habil., D.Sc., full professor	**Neptun code:** MFGFT720014 **Responsible department/institute:** Institute of Exploration Geosciences / Department of Geophysics
	Type of course: C
Position in Curriculum (which semester): 2	**Pre-requisites (if any):** none
Number of Contact Hours per Week (lec.+prac.): 1+1	**Type of Assessment (examination / practical mark / other):** practical mark
Credits: 2	**Course:** full-time **Program:** Earth Science Engineering MSc / Geophysical Engineering

Course Description:
In the frame of the course learn the Geophysical Engineering MSc students how can be the geological and geophysical information from the measured data obtained by recent inversion methods.

Competencies to evolve:

Knowledge: Understands the processes described by the general and specific theories required for the practicing of the fields of earth science engineering (geologist-engineering, geophysical-engineering, geoinformatics-engineering), understands the internal connections between geological processes, and knows the planning and interpretation procedures based on the processes. Has a solid technical and scientific knowledge required for the high-level progress in earth sciences engineering disciplines, among others in numerical methods, technical physics, and their contexts. Based on his/her knowledge, understands the structure of the raw material extraction sector, the technologies used for the extraction and preparation of mineral raw materials, as well as the scope of geo-environmental tasks, their external socio-economic environment and regulatory system. At the application level, knows the GIS methods of computer design and analysis and the geoinformatics systems. Knows in detail the geological and geophysical methods suitable for exploring natural resources.

Ability: Able to apply integrated knowledge of environmental equipment, processes, technologies, and related electronics and informatics.

Attitude: Open and receptive to the knowledge and acceptance of professional, technological development and innovation in the field of environmental protection, and its authentic mediation. Assumes the professional and moral values related to the field of environmental protection. Seeks to plan and carry out tasks independently or in a working group at a professional level. Strives to carry out the required work in a complex approach based on a systems-based and process-oriented way of thinking. Strives to improve the knowledge of both him/herself and subordinated employees through continuous training.

Autonomy and responsibility: Can solve environmental engineering tasks independently, takes decisions carefully, in consultation with the representatives of other (mainly legal, economic, energy) fields, independently, takes responsibility for the decisions. In making decisions, takes into account the basic requirements of occupational health and safety, technical, economic and legal regulations, and engineering ethics. Takes the initiative in solving environmental problems, identifies the shortcomings of the applied technologies, the risks of the processes and initiates the measures to reduce them. Shares the acquired knowledge and experience with formal, non-formal and informal information transfer with practitioners in their field. Evaluates the work of subordinated employees, promotes their professional development by sharing critical remarks, educates employees and subordinates on responsible and moral professional practice.

The short curriculum of the subject:
Solution of the mixed determined inverse problem: solution of the weighted Least Squares method, Marquardt-algorithm. Relationship between the optimization of the damping factor and the condition number. Solution based on the weighted least squares method in data space. Solution based on the weighted Least Squares method in case of mixed determined inverse problem. Solution based on the weighted Least Squares method in the parameter space. Solution of the inverse task by the minimizing of L_p-norm, the method of iterative re-weighting. The qualification of accuracy and reliability of parameter-estimation: covariance and correlation matrices in the parameter space: dissolving matrix, in data and parameter space, generalized inverse, sub-division by singular values. Solutions of the nonlinear inverse task by global optimization methods. The Simulated Annealing and Genetic Algorithm methods. The joint inversion. The series expansion inversion method. Applying the inversions methods in case of different geophysical datasets.

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:

Dobróka M., 2001: The Methods of Geophysical Inversion. University textbook, University of Miskolc. https://www.uni-miskolc.hu/~geofiz/The%20methods%20of%20geophysical%20inversion.pdf
Szabó N.P., 2023: Geophysical inversion. Electronic textbook. https://www.uni-miskolc.hu/~geofiz/Course-Geophysical%20inversion-SZNP.pdf
W. Menke, 1984: Geophysical Data Analysis: Discrete Inverse Theory. Academic Press Inc.
Mrinal Sen and Paul L. Stoffa: Seismic Exploration - Global Optimization: Methods In Geophysical Inversion. Software, Elsevier Science Ltd. 1997.
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.
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
12-Feb	Solution of the mixed determined inverse problem.
19-Feb	Relationship between the optimization of the damping factor and the condition number.
26-Feb	Solution based on the weighted least squares method in data space.
4-Mar	Solution based on the weighted Least Squares method in case of mixed determined inverse problem.
11-Mar	1st mid-term test.
18-Mar	Solution of the inverse task by the minimizing of L_p-norm.
25-Mar	The quality check of inversion results. Stability, accuracy and reliability of parameter-estimation.
1-Apr	Easter Monday.
8-Apr	Solutions of the nonlinear inverse task by global optimization methods.
15-Apr	Global optimization methods. Applications in well logging.
22-Apr	Simulated Annealing. The Genetic Algorithm.
29-Apr	The joint inversion method. The series expansion inversion method.
6-May	2nd mid-term test.
13-May	Repetition of writing tests.

Week	Seminar
12-Feb	Solution of the weighted Least Squares method, Marquardt-algorithm.
19-Feb	The damping factor and the condition number.
26-Feb	Applications of the weighted least squares method.
4-Mar	Solution based on the weighted Least Squares method in the parameter space.
11-Mar	1st mid-term test.
18-Mar	The method of iterative re-weighting.
25-Mar	Covariance and correlation matrices in the parameter space: dissolving matrix, in data and parameter space, generalized inverse, sub-division by singular values.
1-Apr	Easter Monday.
8-Apr	The Simulated Annealing and its variations.
15-Apr	Well logging inversion. Inversion of potential field data.
22-Apr	The Genetic Algorithm methods and its applications.
29-Apr	Applying the inversions methods in case of different geophysical datasets.
6-May	2nd mid-term test.
13-May	Repetition of writing tests.

Sample for the mid-term exam

Please, describe the basics of damped LSQ method (Marquardt algorithm), deduce the normal equation. Please, determine the condition number of normal equation's matrix and show how you choose the appropriate damping factor.

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