MI009	**Applied linear algebra and scientific computing**	L	P	S	ECTS
		4	2	1	9

Objective of the course. Introduce students to the basic ideas and methods of numerical linear algebra used in solving linear systems, least-squares problems, eigenvalue and singular value problems. Teach students how to use computers in science with applications in numerical linear algebra but also in numerical analysis (linear and nonlinear equations, integration, interpolation, simulations and optimizations). With hands on practice students will learn to write sequential and parallel programs in Python, Octave or Matlab and analyze algorithms with good numerical properties. Combine mathematical and computer science knowledge.

Course prerequisites. Undergraduate studies in mathematics and computer science.

Syllabus.

1. **Introduction**. Basic algorithms, structure exploitation, vectorization. Floating point arithmetic. Matrix analysis. Basic ideas of linear algebra. Norm of vectors and matrices. Matrix condition and sensitivity of quadratic and linear systems.
2. **Solving a system of linear equations**. Triangular systems, LU-decomposition, Gaussian algorithm, pivoting. QR decomposition, Householder matrices. Positive definitive systems. Cholesky decomposition.
3. **Iterative methods for solving linear systems.** Standard methods (Jacobi and Gauss-Seidel). Relaxation methods. Large sparse linear systems of equations. Preconditioning. Methods based on Krylov subspaces.
4. **Linear least squares problem**. Orthogonality. Givens matrices, SVD decomposition. Linear least squares linear problem.
5. **Eigenvalue problems**. General eigenvalue problems, properties and decomposition. Schur decomposition, matrix reduction on Hessenberg and triangular form. Symmetric eigenvalue problem, properties and decompositions. Power method, Rayleigh quotient. Iterative methods for finding eigenvalues. Reduction to bilinear form, QR algorithm.
6. **Models with applications of numerical linear algebra**. Heat dissipation of electronic components. Numerical solution of the Poisson equation. System of masses with elastic springs. Material density calculation.
7. **Models with differential equations.** Approximation of boundary problems by finite differences, finite elements. Wave equation, conduction equation.
8. **Discrete Fourier transform.** Trigonometric interpolation. Fast Fourier Transform (FFT).
9. **Case studies**. Models are studied including image deblurring, clustering, and the epidemiological model.

EXPECTED LEARNING OUTCOMES

R.b.	**LEARNING OUTCOMES**
1.	Explain the basic concepts related to vector space and vector and matrix norms.
2.	Apply the Gram-Schmidt orthogonalization procedure.
3.	To use Gaussian algorithm, LU-decomposition, Cholesky's algorithm for solving systems of linear equations.
4.	Construct QR decomposition and apply it to the least squares method.

5.	Explain the basic concepts related to the general and symmetric eigenvalue problem.
6.	Construct models that describe different real problems.
7.	Apply discrete Fourier transform, trigonometric interpolation and fast Fourier transforms.
8.	Implement the processed methods in software tools and illustrate them with examples.
9.	Use mathematical literature of various sources.

CONNECTING LEARNING OUTCOME, ORGANIZING THE TEACHING PROCESS AND ESTIMATING THE LEARNING OUTCOME

ORGANIZATION OF THE TEACHING PROCESS	ECTS	LEARNING OUTCOME **	STUDENT ACTIVITY *	ASSESSMENT METHOD	CREDITS	
					min	max
Attending lectures and exercises	1	1-9	Class attendance, discussion, teamwork, independent work on assignments and short knowledge tests	Signature lists, follow-up of classroom activities, closed-ended assignments	0	4
Homework	1	1-9	Self-Solving Programming Tasks	Checking Correct Solutions (Evaluation)	0	4
Knowledge check (Tests)	3	1-9	Preparing for a Written Assessment	Checking the correct answers (grading)	25	46
Final exam	4	1-9	Repeating the material	Oral exam	25	46
TOTAL	9				50	100

Teaching methods and student assessment: Lectures and exercises are obligatory. The exam consists of a written and an oral part. After completion of lectures and exercises students can take the exam. Acceptable mid-term exam scores replace the written examination.

Can the course be taught in English: Yes.

Basic literature:

1. N. Truhar, Numerička linearna algebra, Odjel za matematiku, Sveučilište u Osijeku, Osijek, 2010.
2. Dianne P. O'Leary, Scientific Computing with Case Studies, SIAM Press , 2009
3. R.Scitovski, Numerička matematika, Odjel za matematiku, Sveučilište u Osijeku, Osijek, 2015.

Recommended literature:

1. G. Golub, C. F. Van Loan, Matrix Computations, Johns Hopkins Univ Pr., 3rd edition, 1996.
2. J. W. Demmel, Applied Numerical Algebra, SIAM 1997.
3. D. Kincaid, W. Cheney, Numerical Analysis, Brooks/Cole Publishing Company, New York, 1996.
4. G. W. Stewart, Matrix Algorithm, SIAM 1998.
5. T. F. Comena, C. van Loan, Handbook for Matrix Computations, SIAM, Press, 1988.