Óbuda University
John von Neumann Faculty of Informatics

TRAINING PROGRAM

APPLIED MATHEMATICS MSC

Budapest, 01 September 2018

DEGREE PROGRAM CURRICULUM

1. Degree program name:

Applied mathematics MSc

2. Field of training:

natural sciences

3. Language of training:

English

4. Training schedule(s) and duration of courses in semesters, number of contact hours:

regular 4 semesters total of 1253 periods

5. Optional specialties:

technical mathematics

6. Number of credits to collect to earn degree:

120 credits

7. Level of qualification and professional qualification as indicated in the degree certificate:

- level of qualification: Master of Science (MSc)
- professional qualification: MSc in Applied Mathematics

8. Study area classification of professional qualification according to the standard classification system of training areas:

461

9. Educational objective:

The aim is to train applied mathematicians who can solve mathematical problems arising in practice in creative ways owing to their professional skill levels reaching scientific research standards, and their high-level mathematical knowledge and modelling experience. They are open to critically assess new scientific results in their special area and related fields. Based on their thorough grounding, they are capable of modelling and solving practical problems, as well as supervising the practical implementation of such solutions. They are prepared to pursue studies at a PhD course.

10. Professional competencies to be mastered:

a) knowledge

- Knowledge of mathematical science methods at system level and in terms of correlations in the fields of algorithm theory, applied analysis, discrete mathematics, operational research, and mathematical statistics.
- Knowledge of the results of applied mathematics in terms of correlations in the fields of algorithm theory, applied analysis, discrete mathematics, operational research, probability calculus, and mathematical statistics.
- Knowledge of deeper and more comprehensive relations and overlapping interconnections between various subdisciplines of applied mathematics.
- Knowledge of abstract mathematical thinking and abstract mathematical concepts.
- Knowledge of the information technology and computer technology body of knowledge as required for generating and simulating applied mathematics models.
- Knowledge of the basics of the theory of differential equations and approximate calculations, as well as their most important applications in the modelling of natural, technical, and economic phenomena.
- Knowledge of the modern theory basics of probability theory and mathematical statistics.
- Knowledge of the basics of encoding theory and cryptography, as well as the theoretical background and applicability of codes and encryptions most widely spread in practice.
- Knowledge of the theoretical background of predictability.
- Knowledge of the use of the most important mathematics and statistics softwares, as well as their mathematical background and the limitations of their applicability.
- Knowledge of the options for the mathematical modelling of technical problems.
- Knowledge of the basics of the theory of differential equations and approximate calculations, as well as their most important applications in the modelling of natural, technical, and economic phenomena.
- Knowledge of the modern theory basics of probability theory and mathematical statistics.
- Knowledge of the geometric and graphic application methods of computers.

b) capabilities

- Able to apply the methods of mathematical science in the fields of algorithm theory, applied analysis, discrete mathematics, operational research, probability calculus, and mathematical statistics.
- Able to create mathematical models of phenomena arising in the surrounding world and to use the achievements of modern mathematics to explain and describe phenomena.
- Able to represent, at an abstract level, correlations observable in practical life.
- Able to combine and use the knowledge and skills acquired in the application fields of mathematics in creative ways to solve problems arising in animate and inanimate nature, in the world of technology and IT, in economy and finance.
- Able to overview as well as to mathematically analyze and model complex systems appearing in nature as well as in technical and economic life, and to prepare decision

making processes. Able to understand the inherent principles of problems, to plan tasks and to execute them at high level.

- Able to formulate potential optimization problems behind decision making situations encountered in practical life, and to communicate any conclusions to be drawn therefrom to non-professionals.
- Able to carry out calculation tasks arising in nature and in technical and economic life by using IT tools.
- Able to identify tasks requiring large-scale calculations and possibly large storage capacity, as well as to analyze alternative approaches.
- Able to clearly present on mathematical results, arguments, and inferences derived therefrom, involving professional communication both in Hungarian and in a foreign language (English).
- Able to professionally formulate the problems of the special field of mathematics both to experts and non-professionals.

c) attitude

- Efforts to familiarize with the latest results of applied mathematics.
- Efforts to apply the achievements of applied mathematics as broadly as possible.
- Efforts to use the applied mathematics knowledge acquired to differentiate between scientifically sustained and insufficiently supported propositions.
- Efforts to notice further correlations between the modern application possibilities of applied mathematics, to synthetize their correlations identified, and to evaluate them at a high level, substantiated by the means of science.
- Open and responsive to using the lines of reasoning, methods and concepts mastered in the field of applied mathematics for new areas of application, and to achieving new results.
- On-going efforts to extend knowledge and to acquire new mathematical competencies.

d) autonomy and responsibility

- Responsible, self-critical and realistic assessment of knowledge acquired in the field of applied mathematics.
- Responsible participation in team work, cooperation even with experts in other special fields based on the critical approach and systemic thinking acquired.
- Independently selecting the methods and procedures to be used in solving certain application problems in possession of high-level knowledge of applied mathematics.
- Deeming it important to perform scientific research and mathematical applications by taking account of the highest ethical norms.
- Aware of the importance of mathematical thinking and precise concept formulation, on the one hand, and of the limits of models in applying mathematics, on the other hand, forming opinions on the basis above.
- Responsibility for representing opinions formed based on the knowledge acquired in applying mathematics.

11. Main training areas:

	Credits
Theoretical foundations (without mathematics BSc)	**20**
Professional core curriculum	**27**
Specialization (technical mathematics)	**38**
Optional subjects (30 with mathematics BSc)	**15**
Thesis work	**20**
Altogether:	**120**

12. Criteria prescribed:

none

13. Foreign language requirements (to earn the degree):

none

14. Knowledge verification:

a) during the study period, by written or verbal reports, written (classroom) tests, by the evaluation of home assignments (designs, measurement records, etc.), mid-semester grading or signature,
b) by preliminary examination passed in the study period,
c) by examination or comprehensive examination passed in the examination period, and
d) by final examination.

15. Criteria for admission to a final examination:

a) Final completion certificate (absolutorium) granted,
b) Thesis approved by the supervisor and an independent reviewer.

Admission to a final examination is subject to a completion certificate being granted. A final completion certificate is issued by the faculty to a student who has complied with the study and examination requirements prescribed in the curriculum – except for the completion of the thesis – and has acquired the credits prescribed.

16. Parts of the final examination:

The final examination consists of defending the thesis and oral examinations taken on the subjects prescribed in the curriculum (time allowed for preparation: at least 30 minutes per subject), to be passed by the student consecutively within the same day.
Subjects (subject groups) comprising, in the aggregate, a body of knowledge corresponding to at least 20 and up to 30 credit points may be designated for the final examination.

The list of questions of the oral examination is made available to candidates 30 days before the date of the final examination.

Candidates may start the examination if their thesis has been accepted by the final examination board with at least *sufficient (2)* qualification. Criteria for making up for a failed thesis are defined by the competent institute.

17. Result of the final examination:

The weighted average of the grades of the thesis (T) and the oral part of the final examination – taking into consideration the number of subjects (S) included in the final examination – as follows:

$$R = (T + S1 + S2 + \ldots + Sm)/(1+m).$$

18. Criteria for issuing a diploma:

a) Successful final examination,
b) Compliance with the foreign language requirement.

19. Dual training option:

not applicable

20. Cooperative training option:

not applicable

21. Date of entry into effect: 01 September 2018

Dated in Budapest, 16 July 2018

Dr. András Molnár, PhD habil.
Dean

Theoretical foundations (for students who have no BSc in mathematics)

<table>
<tr><td>Name:
Linear Algebra</td><td colspan="2">NEPTUN-code:
regular: NMXLA1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="2">Credits: 3
Requirement : practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Magdolna Szőke</td><td>Position:
lecturer</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">Unitary spaces, spectral theorem, canonical forms of polynomial matrices, minimal polynomial of a matrix, theorem of Cayley and Hamilton, Jordan canonical form, eigenvectors, quadratic forms, matrix analysis: eigenvalues and singular values of matrices, spectral theory of self adjoint matrices, matrix polynomials, matrices with positive entries, theorem of Perron and Frobenius.</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory</u>:
A.J. Laub, Matrix Analysis for Scientists and Engineers, SIAM, 2005
<u>Recommended</u>:
Carl. D. Meyer, Matrix analysis and applied linear algebra, SIAM (Society for Industrial and Applied Mathematics) Press, Philadelphia, 2000, ISBN 0-89871-454-0
S. Axler, Linear Algebra Done Right, 2nd ed., Springer, 1997</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Algebra and Number Theory</td><td colspan="2">NEPTUN-code:
regular: NMXAS1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="3">Credits: 4
Requirement: exam</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Magdolna Szőke</td><td colspan="2">Position:
lecturer</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="5" align="center">Course description</td></tr>
<tr><td colspan="5">Algebraic structures, semigroups, groups, rings, fields, lattices. Fundamentals of group theory. Homomorphism, automorphism, endomorphism, isomorphism. Normal subgroup, factor group, homomorphism theorems. Permutation groups. Cayley's Theorem. Lagrange Theorem. Abelian groups, nilpotent groups, solvable groups, simple groups, free groups. Fundamental Theorem of abelian groups. Sylow Theorems. Normalizer, centralizer, conjugay class. Fundamental concepts of ring theory. Commutative rings. Modules, algebras. Integral domain, Ideals, factor rings. Fundamental concepts of number theory. Congruences, Fundamental Theorem of Number Theory. Euler's φ function. Theorems about prime numbers, Waring problems.</td></tr>
<tr><td colspan="5" align="center">Literature</td></tr>
<tr><td colspan="5"><u>Compulsory:</u>
• Peter J. Cameron: Introduction to Algebra, Oxford University Press, 1998

<u>Recommended:</u>
• - M.B. Nathanson, Elementary Methods in Number Theory, Graduate Text in Mathematics, 195, Springer, 2000</td></tr>
</table>

<table>
<tr><td>Name:
Analysis</td><td>NEPTUN-code:
regular: NMXAN1PMNE</td><td colspan="2">Number of periods/week (lec/sem/lab):
regular: 2/1/0</td></tr>
<tr><td colspan="3">Credits: 4
Requirement: practice mark</td><td>Prerequisite:
-</td></tr>
<tr><td>Responsible:
István Vajda</td><td colspan="2">Position:
lecturer</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Course description</td></tr>
<tr><td colspan="4">Elementary real analysis, measure theory, Riemann-Stieljes integral, path integral, Lebesgue integral, inverse function theorem, implicit function theorem, conditional extremum, Hilbert spaces, orthonormal systems, linear operators, Lagrange and Hermite-Fejer interpolation, ordinary differential equations, basics of numerical analysis.</td></tr>
<tr><td colspan="4">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
• E. Hewitt, K. Stromberg, Real and abstract analysis, Springer Verlag, 1965

<u>Recommended:</u>
• B.P. Rynne, A. Martin, Linear Functional Analysis, Springer, 2008
• E. Pap, A. Takaci, Dj. Takaci, Partial Differential Equations through Examples and Exercises, Kluwer Academic Publishers, Dordrecht/Boston/London, 1997, 405 pp.
• E. Pap,: Null-Additive Set Functions, Kluwer Academic Publishers, Mathematics and Its Applications 337, Dordrecht/Boston/London, 1995
• E. Pap, Handbook of Measure Theory, Volume I, II, Elsevier, North-Holland, 2002</td></tr>
</table>

Name: **Geometry and Topology**	***NEPTUN-code:*** regular: NMXGT1PMNE	***Number of periods/week (lec/sem/lab):*** regular: 2/1/0
Credits: 4 ***Requirement:*** exam	***Prerequisite:*** -	
Responsible: Peter NAGY	***Position:*** full prof	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics

Course description

Motions and similarities of the Euclidean plane and space. Circles and spheres. Circle preserving transformations of the plane. The geometry of the sphere surface and elliptic plane. The plane of complex numbers, linear fractional transformation. Real and complex cross ratio, the geometry of the complex projective line. Projective plane and space. The hyperbolic plane and its isometry group. Differential calculus and vector calculus in 3 dimensions. Presentation of curves and surfaces by differentiable vector-valued functions. Coordinate systems. Vector analysis. Topology of surfaces. The concept of topological and metric space, sequences and convergence, compactness and connectedness.

Literature

Compulsory:
- Michèle Audin, Geometry, Springer, Universitext, 2003

Recommended:
- Coxeter, H. S. M. Introduction to Geometry (2nd Ed.). Wiley, New York, 1969
- V. G. Boltyanski, V. A. Efremovich, Intuitive Combinatorial Topology, Springer, 2001

<table>
<tr><td>Name:
Probability Theory and the basics of Mathematical Statistics</td><td>NEPTUN-code:
regular: NMXVS1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/1/0</td></tr>
<tr><td colspan="2">Credits: 3
Requirement: exam</td><td>Prerequisite:
-</td></tr>
<tr><td>Responsible:
Peter KARASZ</td><td>Position:
associate prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="3">Course description</td></tr>
<tr><td colspan="3">Probability space, formula of total probability, Bayes' rule, concept and characterization of random variables, probability distribution and density function, expected value, moments, variance. Transforms of distribution functions (generator and characteristic function, Laplace transform). Joint distribution and density function of random variables, independence of random variables, covariance matrix. Conditional expectation and its properties, formula of total expected value. Convergence notions, Borel-Cantelli lemma, weak and strong law of large numbers, central limit theorems.
Experiment, sample space, statistical sample, statistical functions. Order statistic, empirical distribution function, Glivenko–Cantelli theorem. Consistent, unbiased and efficient estimator, basic statistical functions. Estimation methods: method of moments and maximum likelihood estimation, method of least squares. Point and interval estimation. Fundamentals of hypothesis testing, confidence intervals, Neyman–Pearson lemma, parametric and non-parametric tests.</td></tr>
<tr><td colspan="3">Literature</td></tr>
<tr><td colspan="3"><u>Compulsory:</u>
• -

<u>Recommended:</u>
• Chow, Y. S.,Teicher, H., Probability Theory: Independence, Interchangeability, Martingales. Springer, New York, Heidelberg, Berlin, 1978
• Devore, J.L., Berk, K.N. Modern Mathematical Statistics with Applications (2nd ed.), Springer, New York, Dordrecht, Heidelberg, London, 2012
• Feller, W., An Introduction to probability Theory and its Applications, Vol. I. (3rd ed.). Wiley, 1970, Vol. II. (2nd ed.), Wiley, New York, Chichester, Brisbane, Toronto, 1971
• Shiryaev, A.N., Problems in Probability. Springer, New York, Heidelberg, Dordrecht, London, 2012
• Mittelhammer, R., Mathematical Statistics for Economics and Business (2nd ed.). Springer, New York, Heidelberg, Dordrecht, London, 2013</td></tr>
</table>

<table>
<tr><td>Name:
Introduction to Matlab Programming</td><td>NEPTUN-code:
regular: NMXBM1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="2">Credits: 2
Requirement: exam</td><td>Prerequisite:
-</td></tr>
<tr><td>Responsible:
Szabolcs Sergyán</td><td>Position:
associate prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="3">Course description</td></tr>
<tr><td colspan="3">Matlab environment, variable types, handling of arrays, m-files, generating executable codes, integration of C++ and Matlab codes, importing and exporting excel files, graphics, toolboxes: symbolic Math, PDE, Statistics, Curve Fitting, Optimization, Neural Network toolboxes, numerical methods..</td></tr>
<tr><td colspan="3">Literature</td></tr>
<tr><td colspan="3"><u>Compulsory:</u>
• Danaila, P. Joly, S.M. Kaber, M. Postel, An Introduction to Scientific Computing -- Twelve Computational Projects Solved with MATLAB, Springer, 2007
<u>Recommended:</u>
• C. Moler, Numerical Computing with MATLAB. The Mathworks Inc., 2004</td></tr>
</table>

Professional core curriculum

<table>
<tr><td>Name:
Algorithm Theory</td><td>NEPTUN-code:
regular: NMXAE1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/2/0</td></tr>
<tr><td colspan="2">Credits: 5
Requirement: exam</td><td>Prerequisite:
-</td></tr>
<tr><td>Responsible:
Aurel GALANTAI</td><td>Position:
full prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="3">Course description</td></tr>
<tr><td colspan="3">Basic mathematical concepts, formal languages and automata, Algorithms, computability and decision problems. Analysis of algorithms. Turing machines, recursive functions. Algorithmic decidability, computability and complexity. Computational complexity.Computational complexity theory: P, NP, coNP classes and their connections, NP-complete problems.</td></tr>
<tr><td colspan="3">Literature</td></tr>
<tr><td colspan="3"><u>Compulsory:</u>
• A. Maruoka: Concise Guide to Computation Theory, Springer, 2011
• E.E. Reiter, C. M. Johnson: Limits of Computation, CRC Press, 2013

<u>Recommended:</u>
• H. S Wilf: Algorithms and Complexity, Summer, 1994
• T. H. Cormen, C. E. Leiserson,, R. L. Rivest, C. Stein: Introduction to algorithms Cambridge: MIT press, 2001</td></tr>
</table>

Name: Discrete Mathematics	**NEPTUN-code:** regular: NMXDM1PMNE	**Number of periods/week (lec/sem/lab):** regular: 2/2/0
Credits: 5 ***Requirement:*** exam		***Prerequisite:*** -
Responsible: Gábor Hegedűs	***Position:*** assoc. prof	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics
Course description		
Field extensions. Algebraic and transcendent extensions. Normal extensions. The fundamental theorem of algebra. Galois Theory. Finite fields. Basic concepts of Graph Theory. Turing Machine. Forests and trees. Regular graphs. Connectivity, components, Euler circle, Euler's theorem. Hamilton Circle, Dirac and Ore Theorems. Isomorphism of graphs. Directed graphs, tournaments, multigraphs. Matching, bipartite graphs, Hall Theorem. Tutte's 1-Factor Theorem. Extremal problems. Turán's Theorem. Vertex colouring, edge colouring. Vizing's Theorem, chromatic number, Brook's Theorem. Ramsey-type Theorems. Trees and free groups. Block systems.		
Literature		
Compulsory: • Béla Bollobás: Graph Theory, Springer-Verlag New York Inc., 1979. Recommended: • -		

Name: **Interpolation and Approximation**	**_NEPTUN-code:_** regular: NMXIA1PMNE	**_Number of periods/week(lec/sem/lab):_** regular: 2/0/0
Credits: 2 **_Requirement:_** exam		**_Prerequisite:_** -
Responsible: Aurel GALANTAI	**_Position:_** full prof	**_Faculty and Institute name:_** John von Neumann Faculty of Informatics Institute of Applied Mathematics

Course description

Orthogonal polynomials. Pointwise and uniform convergence of trigonometric and orthogonal polynomial series. Fourier Transformation. Elements of approximation theory. Stone's theorem, Bohman-Korovkin theorem. Best approximation by polynomials. Jackson's theorems. Interpolation. Spline functions. Approximation by rational functions. The Lebesgue function of Lagrange interpolation. Erdős-Bernstein conjecture on the optimal nodes. Grünwald-Marczinkiewicz theorem.

Literature

Compulsory:

- J.H. Ahlberg, E.N. Nilson, The theory of splines and their applications, Academic Press, 1967
- J. Bustamante, Algebraic approximation: A Guide to Past and Current Solutions, Birkhauser, 2012
- E.W. Cheney, Introduction to approximation theory, AMS Chelsea Publishing, 2000

Recommended:

- P.J. Davis, Interpolation and approximation, Dover, 1975
- G.G. Lorentz, Approximation of functions, AMS Chelsea Publishing, 2005
- G. Mastroianni, G.V. Milovanovic, Interpolation Processes, Basic Theory and Applications, Springer, 2008
- T.J. Rivlin, An introduction to the approximation of functions, Dover, 1981

Name: **Differential Equations**	***NEPTUN-code:*** regular: NMXDE1PMNE	***Number of periods/week (lec/sem/lab):*** regular: 2/1/0

Credits: 3 ***Requirement:*** exam	***Prerequisite:*** -

Responsible: Márta Takács	***Position:*** associate prof	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics

Course description

Stability theory. Periodic solutions. Boundary-value problems for linear differential equations. The fundamental problem of the calculus of variations. Euler–Lagrange differential equations. Geometric methods in mechanics. Lagrangian and Hamiltonian systems. Legendre transformation. Euler–Lagrange equations, Hamilton equations. Symmetries and conservation laws. Basic concepts in the theory of partial differential equations. Characteristic functions, first integrals. Linear and quasilinear equations of first order. Theory of characteristics of first order equations, Cauchy problem. Classification of second-order linear partial differential equations, reduction to canonical form. Goursat and Cauchy problem for hyperbolic equations. Mixed problem for wave equation. Method of Fourier. Mixed problem for heat equation, maximum-theorem. Cauchy problem for heat equation, Duhamel principle, boundary-value problems for potential equations. Fixed point theorems and their applications.

Literature

Compulsory:

- E. Pap, A. Takači, Dj. Takači, Partial Differential Equations through Examples and Exercises, Kluwer Academic Publishers, Dordrecht/Boston/London, 1997

Recommended:

- V. I. Arnol'd, Mathematical methods of classical mechanics, Graduate Texts in Mathematics, Springer-Verlag, 1989.
- J. H. Heinbockel, Introduction to the Variational Calculus, Trafford on Demand Pub, 2007.
- C. C. Ross, Differential Equations, An Introduction with Mathematica, Springer, Second edition, 2004

<table>
<tr><td>Name:
Operations Research</td><td>NEPTUN-code:
regular: NMXOM1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/2/0</td></tr>
<tr><td colspan="2">Credits: 5
Requirement: exam</td><td>Prerequisite:
-</td></tr>
<tr><td>Responsible:
Janos FULOP</td><td>Position:
assoc. prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="3" align="center">Course description</td></tr>
<tr><td colspan="3">Optimization models (continuous vs discrete optimization; deterministic vs stochastic optimization). Linear optimization: classic results (theorems of alternatives, duality, Minkowsky-Weyl theorem); Pivot algorithms (simplex, criss-cross); Interior point methods (logarithmic barrier, Karmarkar); Ellipsoid method; Practical problems of linear optimization. Nonlinear optimization: classic results of convex optimization (separation theorems, convex Farkas theorem, Karush-Kuhn-Tucker theorem, Lagrange function and saddle-point theorem); Special problems of nonlinear optimization (quadratic optimization, geometric programming); Methods (Newton method, reduced gradient method, interior point algorithms); Practical problems of nonlinear programming. Basic models of stochastic programming and solution methods; Practical problems of stochastic optimization. Combinatorial optimization: classic results (max-flow min-cut theorem, König-Egerváry duality, Hoffman theorem); Polyhedral combinatorics (applications of totally unimodular matrices, total dual integrality, matching polytope); Graph algorithms (Hungarian method, Edmonds-Karp algorithm, preflow-push algorithm, minimal cost flow problem); Practical problems of combinatorial optimization. Algorithmic approaches for NP-complete problems (dynamic programming, Lagrangian relaxation, branch-and-bound, cutting plane methods, heuristic algorithms); Practical problems of integer and global optimization.</td></tr>
<tr><td colspan="3" align="center">Literature</td></tr>
<tr><td colspan="3"><u>Compulsory:</u>
Bertsimas, D., Tsitsiklis, J.: Introduction to Linear Optimization. Athena Scientific, Belmont, MA, 1997
Schrijver, A.: Theory of Linear and Integer Programming, Wiley, 1999
Bazaraa, M.S., Sherali, H.D., Shetty, C.M.: Nonlinear Programming, Wiley, 3rd ed., 2006
<u>Recommended:</u>
Prékopa, A.: Stochastic Programming, Kluwer Academic Publishers, 1995
Roos, C., Terlaky, T., Vial, T.: Interior Point Methods for Linear Optimization, Springer Science, 2006
Lawler, E.L.: Combinatorial Optimization: Networks and Matroids, Holt, Rinehart and Winston, 1976</td></tr>
</table>

<table>
<tr><td>Name:
Stochastic Processes and their applications</td><td>NEPTUN-code:
regular: NMXSF1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/2/0</td></tr>
<tr><td colspan="2">Credits: 5
Requirement: exam</td><td>Prerequisite:
NMXVS1PMNE Probability theory and the basics of mathematical statistics</td></tr>
<tr><td>Responsible:
Peter KARASZ</td><td>Position:
assoc. prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="3" align="center">Course description</td></tr>
<tr><td colspan="3">The notion of stochastic processes. Square integrable processes, weak sense stationary stochastic processes, special models, discrete and continuous power spectrum, linear filters, prediction of processes. Elements of time series analysis, estimation of mean value and covariance function. Periodogram, estimation of power spectrum, smoothing periodogram. Strict sense stationary processes, ergodic theorems. Autoregressive and moving average processes and estimation of their parameters. Bilinear processes and testing linearity. Wiener process and its properties, Ito stochastic integrals, stochastic differential equations and their weak and strong solutions, linear stochastic differential equations, diffusion processes.</td></tr>
<tr><td colspan="3" align="center">Literature</td></tr>
<tr><td colspan="3"><u>Compulsory:</u>
-
<u>Recommended:</u>
Brockwell, P.J., Davis, R.A.: Time Series: Theory and Methods (2nd ed.), Springer, New York, Berlin, Heidelberg, 1991
Shiryaev, A.N.: Problems in Probability, Springer, New York, Heidelberg, Dordrecht, London, 2012
Shumway, R.H., Stoffer, D.D.: Time Series Analysis and Its Applications (3rd ed.), Springer, New York, Dordrecht, 2011
Steele, J.M.: Stochastic Calculus and Financial Applications. Springer, New York, Berlin, Heidelberg, 2001</td></tr>
</table>

Specialization (technical mathematics)

<table>
<tr><td>Name:
Engineering Computational Methods I</td><td colspan="2">NEPTUN-code:
regular: NMXMS1PMNE</td><td>Number of periods/week:(lec/sem/lab)
regular: 2/0/2</td></tr>
<tr><td colspan="2">Credits: 5
Requirement: exam</td><td colspan="2">Prerequisite:
NMXIA1PMNE Interpolation and Approximation
NMXDE1PMNE Differential Equations</td></tr>
<tr><td>Responsible:
Aurel GALANTAI</td><td>Position:
full prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Course description</td></tr>
<tr><td colspan="4">Large scale linear algebra problems, iterative methods. Discretization of linear boundary value problems. Variational problems, Ritz method, finite element method. Galerkin finite element method. Grid generations, error estimates, stability of methods. Software packages.</td></tr>
<tr><td colspan="4">Literature</td></tr>
<tr><td colspan="4">Compulsory:
• U.M. Ascher, R.M.M. Mattheij, R.D. Russell, Numerical Solution of Boundary Value Problems for Ordinary Differential Equations, SIAM, 1995
• S.C. Brenner, L. Ridgway Scott, The Mathematical Theory of Finite Element Methods, 3rd ed., Springer, 2008
• C.G. Broyden, M.T. Vespucci, Krylov Solvers for Linear Algebraic Systems, Elsevier, 2004

Recommended:
• Iserles, A First Course in the Numerical Analysis of Differential Equations, Cambridge University Press, 2009
• K.W. Morton, D.F. Mayers, Numerical Solution of Partial Differential Equations, Cambridge University Press, 2005</td></tr>
</table>

<table>
<tr><td>Name:
Fourier Analysis and Series</td><td colspan="2">NEPTUN-code:
regular: NMXFA1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="2">Credits: 2
Requirement: exam</td><td colspan="2">Prerequisite:
NMXIA1PMNE Interpolation and approximation</td></tr>
<tr><td>Responsible:
Jozsef TAR</td><td>Position:
full prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">Fourier analysis and function series: Fourier series, Dirichlet kernel, Fejér's example, inversion formula, completeness of Hermite and Laguerre polynomials, discrete Fourier transform, quick Fourier transform, wavelet transform.</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
• A. Vretblad, Fourier Analysis and its Applications, Springer, 2003

<u>Recommended:</u>
• E. Chu, Discrete and Continuous Fourier Transforms: Analysis, Applications and Fast Algorithms, CRC Press, 2008
• M.A. Pinsky, Introduction to Fourier Analysis and Wavelets, AMS, 2009
• T. Butz, Fourier Transformation for the Pedestrians, Springer, 2006</td></tr>
</table>

<table>
<tr><td>Name:
Multivariate Statistical Methods</td><td colspan="2">NEPTUN-code:
regular: NMXTS1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/2</td></tr>
<tr><td colspan="2">Credits: 5
Requirement: exam</td><td colspan="2">Prerequisite:
NMXVS1PMNE Probability Theory and basics of Mathematical Statistics</td></tr>
<tr><td>Responsible:
Tamás Ferenci</td><td>Position:
lecturer</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">Multivariate distributions, multivariate normal distribution, conditional distributions, Wishart-distributions, Cochran's theorem. ML estimation of the parameters of the multivariate normal distribution, hypothesis testing. Multidimensional regression, analysis of variance and covariance. Principal components- and factor analysis. Analysis of contingency tables, discriminant analysis, cluster analysis, multidimensional scaling. Threshold, probit- and logit models. Statistical program packages for multivariate statistics.</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
• -

<u>Recommended:</u>
• B Flury: A First Course in Multivariate Statistics, Springer, 1997.
• K.V. Mardia, J.T. Kent and J.M. Bibby: Multivariate Analysis, Academic Press, 1979.
• C. R. Rao: Linear statistical inference and its applications, Wiley and Sons, 1968.</td></tr>
</table>

<table>
<tr><td>Name:
System and Control Theory</td><td colspan="2">NEPTUN-code:
regular: NIXRI1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/2</td></tr>
<tr><td colspan="2">Credits: 5
Requirement: exam</td><td colspan="2">Prerequisite:
NMXDE1PMNE Differential Equations</td></tr>
<tr><td>Responsible:
Levente Kovács</td><td>Position:
full prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Course description</td></tr>
<tr><td colspan="4">The analysis of dynamical systems: nonlinear systems, qLPV, LPV and LTI systems. Similarity transformations. Spectrum of matrices: algebraic and geometric multiplicity of the eigenvalues. Eigenvectors, generalized eigenvectors, Jordan chains. Defective and diagonalizable matrices. Nilpotent matrices. The Gram-Schmidt Algorithm. Jordan’s Canonical Form of matrices and their matrix exponentials. The Cayley-Hamilton Theorem. Stability of LTI systems. Controllability of LTI systems for discrete and continuous cases. The frequency picture. Transfer Function. Impulse Response. Frequency Response; MacMillen order. Spectral Factorization.</td></tr>
<tr><td colspan="4">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
• -

<u>Recommended:</u>
• A. Bacciotti, L. Rosier: Lyapunov Functions and Stability in Control Theory, 2nd ed., Springer, 2005
• Chi-Tsong Chen, Linear Systems Theory and Design, 3rd ed., Oxford University Press, 1999
• T. Kailath, Linear Systems, Prentice-Hall, Inc., 1980
• J. K. Tar, L. Nádai, Imre J. Rudas, System and Control Theory with Especial Emphasis on Nonlinear Systems, TYPOTEX, Budapest, 2012, ISBN 978-963-279-676-5</td></tr>
</table>

<table>
<tr><td>Name:
Partial Differential Equations</td><td>NEPTUN-code:
regular: NMXPD1PMNE</td><td colspan="2">Number of periods/week (lec/sem/lab):
regular: 2/0/2</td></tr>
<tr><td colspan="2">Credits: 5
Requirement: exam</td><td colspan="2">Prerequisite:
NMXDE1PMNE Differential Equations</td></tr>
<tr><td>Responsible:
Vilmos ZOLLER</td><td>Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">Initial and boundary value problems for hyperbolic and parabolic equations, weak solutions of elliptic boundary problems, Sobolev spaces, generalized functions, Bessel functions, fundamental solutions, systems of partial differential equations, linear models and applications: Maxwell’s equations and the equations of elasticity.</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
V.I. Arnold, Lectures on Partial Differential Equations. Springer, Berlin, 2004
<u>Recommended:</u>
T.v. Kármán, M.A. Biot, Mathematical Methods in Engineering, McGraw-Hill, 1940
A. N. Tychonov and A.A. Samarski. Partial differential equations of mathematical physics, Holden-Day, San Francisco, 1964
Foundations of the Classical Theory of Partial Differential Equations, ed. by Yu.V.Egorov and M. A. Shubin, Encyclopaedia of Mathematical Sciences 30, Springer, 1998</td></tr>
</table>

<table>
<tr><td>Name:
Engineering Computational Methods II</td><td colspan="2">NEPTUN-code:
regular: NMXMS2PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/2</td></tr>
<tr><td colspan="3">Credits: 5
Requirement: exam</td><td>Prerequisite:
NMXMS1PMNE Computational Methods in Engineering I</td></tr>
<tr><td>Responsible:
Imre RUDAS</td><td colspan="2">Position:
full prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">Numerical optimization: global extremum, univariate and linr minimization, conjugate gradient method. Linear programming, simplex method. Constrained optimization, Lagrange multiplicator, convex programming, duality. Software packages, numerical and symbolic computations. The use of numerical and symbolic computer packages.</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
J.F. Bonnans, J.C. Gilbert, C. Lemaréchal, C.A. Sagastizabal, Numerical Optimization: Theoretical and Practical Aspects, 2nd ed., Springer,2006
R. Fletcher, Practical Methods of Optimization, 2nd ed, Wiley, 2000
P.E. Gill, W. Murray, M.H. Wright, Practical Optimization, Academic Press, 1997
<u>Recommended:</u>
J. J. Moré, S.J. Wright, Optimization Software Guide, SIAM, 1993
J. Nocedal, S.J. Wright, Numerical Optimization, Springer, 1999
C. T. Kelley, Iterative Methods for Optimization, SIAM, 1999
J. D. Pintér, Global Optimization in Action, Kluwer, 1996</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Information- and coding theory</td><td>NEPTUN-code:
NMXIK1PMNE</td><td>Number of periods/week:
full-time: 3 lec + 0 sem + 0 lab</td></tr>
<tr><td colspan="2">Credit: 5
Requirement: exam</td><td colspan="2">Prerequisite:
NIXRI1PMNE System and control theory</td></tr>
<tr><td>Responsible:
Aurél GALÁNTAI, D.Sc.</td><td>Position:
professor, habil.</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Way of assessment:
– written exam</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Basics of information theory, entropy, variable length source coding, Huffman code. The communication channel: conditional entropy, mutual information, channels and their capacities, decoding, ideal observer. Basics of error-correcting codes: Galois fields, vector spaces. Linear codes: Hamming code, orthogonal and first order Reed-Müller code. Cyclic codes. Data compression. Theoretical limits of compression. Arithmetic coding. Important compression techniques: Lempel-Ziv algorithms, the Burrows-Wheeler method. Elements of cryptology. Classical encryptions. Model of algorithmic attacks and cryptanalysis of classical encryptions. DES and AES. Public key encoding: basics and the RSA algorithm.</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Image processing and computer graphics</td><td>NEPTUN-code:
NIXSK1PMNE</td><td>Number of periods/week:
full-time: 2 lec + 0 sem + 2 lab</td></tr>
<tr><td colspan="2">Credit: 4
Requirement: mid-term mark</td><td colspan="2">Prerequisite:
NMXSF1PMNE Stochastic processes and their applications</td></tr>
<tr><td>Responsible:
Zoltán VÁMOSSY, Ph.D.</td><td>Position:
associate professor</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4">Way of assessment:
– successful home project + min. 50% in the tests written during the semester</td></tr>
<tr><td colspan="4">Course description:</td></tr>
<tr><td colspan="4">Homogeneous coordinates and 3D transformations. Modeling objects. Camera models, orthographic and perspective projection. Objects in 3D projections. The imaging basics. Gray scale and color images features: resolution, histogram, etc. Typical image noises, distortions. Image enhancements, image filtering. Histogram and modification in compensation. Methods of edge detection, edge enhancement, smoothing. Line and curve detection, Hough transform. Morphological operations. Texture analysis. Frequency domain methods, FFT, DFT, filtering, deconvolution. Image segmentation. Edge and region-based methods. Detecting corner points (Harris, KLT), analyzing image regions. Invariant features, edges, texture, color, topology. PCA transformation. Camera calibration. Motion detection, object tracking. Optical flow models and calculations. SSD algorithms. Stereo methods, epipolar geometry. Model-based image processing: active contour methods, splines, ASM, AAM. Content-based image retrieval methods. Outlook for parallelization opportunities, multithreading and GPGPU implementations.</td></tr>
</table>

Optional subjects

<table>
<tr><td colspan="2">Name:
Control theory in Robotics</td><td colspan="2">NEPTUN-code:
regular: NIVRM1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="3">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Imre RUDAS</td><td colspan="2">Position:
full prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="5" align="center">Course description</td></tr>
<tr><td colspan="5">Kinematics: Operations with rigid bodies: rotations and translations, Lie Groups. Quaternions, Spinors, Homogeneous Matrices. The Rodrigues Formula and the Denavit-Hartenberg Conventions. Open Kinematic Chains and the Differential Approach Redundant Robot Arms. Kinematic Singularities.
Dynamic Modeling: The use of the Homogeneous Matrices in building up the Dynamic Model. Modified Denavit-Hartenberg Conventions.
Model-based Dynamic Control: PTP, CP, and CTC Controllers. Robust VS/SM Controller.
Model-based Adaptive Control: Lyapunov's „Direct Method": Adaptive Inverse Dynamics Controller. The Slotine-Li Adaptive Controller, Optimal Control. Nonholonomic systems; Friction Models; Environmental Dynamic interactions. the Fractional Order derivatives in robot control</td></tr>
<tr><td colspan="5" align="center">Literature</td></tr>
<tr><td colspan="5"><u>Compulsory:</u>
• -

<u>Recommended:</u>
• M. Vukobratovic, V. Potkonjak: Scientific Fundamentals of Robotics, Vol. 1, Dynamics of Manipulation Robots: Theory and Application, Springer- Verlag, 1982
• M. Vukobratovic, D. Stokic: Scientific Fundamentals of Robotics 2: Control of Manipulation Robots, Theory and Application, Springer-Verlag New York, Inc. Secaucus, NJ, USA, 1985, ISBN: 038711629
• E. Bryson, Jr., Yu-Chi Ho: Applied Optimal Control, Hemisphere, 1975
• J-J.E. Slotine, W. Li, Applied Nonlinear Control, Prentice Hall International, Inc., Englewood Cliffs, New Jersey 1991
• A.M. Lyapunov, Stability of motion, Academic Press, New–York and London, 1966</td></tr>
</table>

Name: **Geometric Algorithms**	**_NEPTUN-code:_** regular: NMVGA1PMNE	**_Number of periods/week (lec/sem/lab):_** regular: 2/0/0

Credits: 2 **_Requirement:_** practice mark	**_Prerequisite:_** -

Responsible: Gyula HERMANN	**_Position:_** assoc. prof	**_Faculty and Institute name:_** John von Neumann Faculty of Informatics Institute of Applied Mathematics

Course description

Polygon triangulation. Polygon area. Polygon Partitioning. Monotone partitioning. Linear-Time Triangulation. Implementation issues. Definition of Convex Hulls. The convex hull of planer point sets. Gift wrapping algorithm. Description and complexity analysis of the Quick Hull and the Graham algorithms. Incremental algorithm. Divide and conquer. Convex hull of special point sets. Polyhedrons. The hull algorithm. Boundary representation. Application in measurement technology. Delaunay triangulation and algorithm. Voronoi diagrams. Application in tool path generation. Search and intersection. Point – polygon distance. Intersection of polygons. Application in computer graphics: hidden line and hidden surface algorithms. Motion planning. Shortest path determination. Robot arm motion. Collision free path.

Literature

Compulsory:

- J. O'Rourke: Computational Geometry in C
- M. de Berg, O. Cheong, M. van Kreveld, M. Overmars: Computational Geometry

Recommended:

- Edelsbrunner:, Algorithms in Combinatorial Geometry
- M.R. Garey, D.S. Johnson, F.P. Preparata, R.E. Tarjan: Triangulating a simple polygon, Information Processing Letters 7, 175-179, 1978
- Kallay, M.: The complexity of incremental convex hull algorithms in Rd, Information Processing Letters 19, 197, 1984
- D.E. Knuth, Sorting and searching, in The Art of Computer Programming

<table>
<tr><td>Name:
Mathematical Logic and Its Applications</td><td colspan="2">NEPTUN-code:
regular: NMVML1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="2">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Marta TAKACS</td><td>Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">Basics of mathematical logic. From the philosophy to the mathematical logic.
Predicate logic. Semantic and syntax. Normal forms. Resolution. Reasoning. The language of the first order logic. The first order structure. The formalism. Mathematical logic and the set theory. Formula reduction. Proof Theory.
The Hilbert system. The basics of the logical programming.
Further logical models (Lukasiewitz, modal, temporary, fuzzy)</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
Marta Takacs: the prepared slides
<u>Recommended:</u>
Wolfgang Rautenberg "A Concise Introduction to Mathematical Logic"
Jon Barwise "Handbook of Mathematical Logic"
Jean Heijenoort "From Frege to Gödel"</td></tr>
</table>

<table>
<tr><td colspan="2">Name:
Formal Methods in Computer Science</td><td colspan="2">NEPTUN-code:
regular: NMVFM1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="3">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Marta TAKACS</td><td colspan="2">Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="5" align="center">Course description</td></tr>
<tr><td colspan="5">Formal models in IT systems. System model construction steps. Model validation and verification. State description.
The specified logical approach (temporary logic).
Petri nets. The basic elements of the Petri nets. The structure PN (P,T,E). The dynamic properties of the PN. Stochastic behaviour of the PN. Token game - enabled transitions. Extended PN structure (timed PN, capacity boundaries, others). The Coloured PN. The reductive technologies. Petri nets in applications (problems, software-based constructions of the PN).
Agent technologies. The work-flow and data flow models (historical overview, the basic concepts of the model construction - hierarchical construction). Completeness, consistency of the systems.
The UML and UML type description of the IT system model.</td></tr>
<tr><td colspan="5" align="center">Literature</td></tr>
<tr><td colspan="5"><u>Compulsory:</u>
• Takács Márta: the prepared slides

<u>Recommended:</u>
• W. Reisig, G. Rozenberg (eds), Lectures on Petri Nets, Vols 1-2, Springer, 1999
• S. Russell, P. Norvig, Artifical Intelligence: A Modern Approach, Prentice-Hall, 1995
• J-R. Abrial, The B-Book, Cambridge University Press, 1996</td></tr>
</table>

<table>
<tr><td>Name:
Simulation Methods</td><td colspan="2">NEPTUN-code:
regular: NMVSM1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 3/0/1</td></tr>
<tr><td colspan="3">Credits: 4
Requirement: exam</td><td>Prerequisite:
-</td></tr>
<tr><td>Responsible:
Laszlo SZEIDL</td><td colspan="2">Position:
full prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4">Compulsory:
• -

Recommended:
• Devroye, L., Non-Uniform Random Variate Generation, Springer, New York, Berlin, Heidelberg, Tokyo, 1986
• Glasserman, P., Monte Carlo methods in Financial Engineering. Springer, New York, 2003
• Lakatos, L., Szeidl, L., Telek, M., Introduction to Queueing Systems with Telecommunication Applications. New York, Heidelberg, Dordrecht, London, 2013
• Thomopoulos, N.T., Essentials of Monte Carlo Simulation. Statistical Methods for Building Simulation Models. Springer, New York, Heidelberg, Dordrecht, London, 2013</td></tr>
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<table>
<tr><td>Name:
Differential Geometry</td><td colspan="2">NEPTUN-code:
regular: NMVDG1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="2">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Peter NAGY</td><td>Position:
full prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4">Course description</td></tr>
<tr><td colspan="4">Arc-length of a curve. Tangent vector, normal plane, osculating plane. Curvature and torsion. Frenet equations. Cylindrical helix, Bertrand curves. Four-vertex theorem. Evolute and involute. Regular surfaces, parametrization. Tangent plane, arc-length of curves on a surface, metric fundamental form. Second fundamental form, Meusnier theorem. Principal, mean and Gaussian curvatures, Euler theorem. Normal spherical map of a surface, umbilical surfaces. Variation of the arc-length, Euler-Lagrange equation, geodetics. Normal coordinates, exponential map. Gauss-Bonnet theorem. Surfaces of constant curvature. Pseudosphere, differential geometric model of the hyperbolic plane.</td></tr>
<tr><td colspan="4">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
• M. P. do Carmo, Differential Geometry of Curves and Surfaces, Prentice-Hall, New Jersey, 1976

<u>Recommended:</u>
• Barrett O'Neill, Elementary Differential Geometry, Revised 2nd Edition, Academic Press (Elsevier), 2006
• Bär, Christian - Elementary differential geometry. Cambridge University Press, 2010</td></tr>
</table>

<table>
<tr><td>Name:
Geometric Foundations of Robotics</td><td>NEPTUN-code:
regular: NMVRG1PMNE</td><td colspan="2">Number of periods/week:(lec/sem/lab)
regular: 2/0/0</td></tr>
<tr><td colspan="2">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Peter NAGY</td><td>Position:
full prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">Classical matrix groups, power series, exponential function of matrices One-parameter matrix groups. Tangent matrix at the unit element. Lie groups, Lie algebras, exponential map. Lie algebras and matrix groups of 2 and 3 dimension. Isometry group of the Euclidean plane. One-parameter plane motions as differentable curves int he motion group. Instantaneous velocity, Euler-Savary equation. Inflexion circle, Ball's point, Burmester's points. Frenet and Darboux motion, elliptical and inverse motion. Quaternions and the group of 3-dimensional rotations. Rotations and Euler angles. Representation of rotations by quaternions. Spherical kinematics. The group of motions of the Euclidean space, helical motion, spatial kinematics.</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
• J. M. Selig, Geometric fundamentals of robotics, Springer Verlag, 2005

<u>Recommended:</u>
• O. Bottema, B. Roth, Theoretical Kinematics, North-Holland, 1979.
• A. Karger, J. Novak, Space Kinematics and Lie Grups, Gordon and Breach Sci. Publ., Prague, 1978</td></tr>
</table>

Name: **Numerical Analysis**	NEPTUN-code: regular: NMVNAPMNE		Number of periods/week (lec/sem/lab): regular: 2/0/0
Credits: 2 ***Requirement:*** practice mark		***Prerequisite:*** -	
Responsible: Jozsef ABAFFY	***Position:*** prof. emeritus	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics	

Course description

Gauss elimination and its error analysis. Conjugate gradient method. Iteration methods. Iteration methods for sparse matrices. ABS methods. Hessenberg's transformation and QR factorization. Eigen value problems. Methods of Housholder and Lánczos. Least square problems and determination of the degree. Approximation by orthogonal polynomials. Inverse of a matrix. Optimizations of one variable problem (golden section method, parabola methods, Newton and other methods.) Armijo-Goldstein conditions. Backtracking. Methods of unconstrained optimizations (conjugate direction, Newton and quasi-Newton methods. BFGS method).

Relationship between optimization and system of nonlinear equations. Solution of one variable equation by secant, Newton and modified Newton's methods. Solution of nonlinear system of equations by gradual approximation method, by generalized Newton's method. Broyden's method.

Literature

Compulsory:

- J.H. Wilkinson: The Algebraic Eigenvalue Problem, Oxford University Press, 1965
- G.W. Stewart: Introduction to Matrix Computation, Academic Press, London, 1973
- C.G. Broyden: Basic Matrices: An introduction to matrix theory and practice, The Macmilla Ltd,
- London and Basingstoke, 1975
- J.E.Dennis,JR. Robert B.Schnabel: Numerical Methods for Unconstrained Optimization and No
- Equations, Prentice-Hall. Inc, Englewood Cliffs, New Jersey 07632, 1983

Recommended:

- J. Abaffy, E. Spedicato, ABS Projection Algorithms: MathematicalTechniques for Linear and
- Nonlinear Equations, Ellis Horwood Ltd, 1989,
- D.Houcque:Introduction to MATLAB for engineering students, Northwestern University, Version 1.2, 2005

Name: **Modeling**	NEPTUN-code: regular: NMVMO1PMNE	Number of periods/week (lec/sem/lab): regular: 1/0/1
Credits: 2 ***Requirement:*** practice mark	***Prerequisite:*** -	
Responsible: Laszlo HORVATH	***Position:*** full prof	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Mathematics

Course description

Role of mathematics in scientific grounding of virtual engineering. Virtual space, model space, coordinate systems, and transformations. Description and representation of objects in model space. *Boundary representation* of solid shapes: mapping curve and surface representation in topological structure. Parametric equation of curves and surfaces. Control of curve and surface shape by interpolation and approximation. Blending functions, segmentation of curve, and knot vector. Non-uniform rational B-spline curve and surface representation. Eulerian polyhedron model and its application as local and global topology in solid boundary representation. Euler operators, manifold and non-manifold topologies. *Topology based model object definition methods* including definition and recognition of form features, connected bodies and surfaces, relative placing of bodies, and degrees of freedom in solid body structures. Definition of curves and surfaces on *cloud of captured or calculated points* including tessellation, filtering, and scan and scan based curve generation. *Finite element model* and its analysis: numerical basics, associative and adaptive mesh definitions, finite element characteristics, and essential linear, non-linear, static and dynamics solutions. *Situation and event control of engineering object definition* using optimizing algorithms, mathematical functions, as well as rule and reaction sets.

Literature

Compulsory:

- G. Farin, J. Hoschek, M.-S. Kim, J. Hoschek, M.-S. Kim, Handbook of Computer Aided Geometric Design, Elsevier, ISBN: 978-0-444-51104-1, 2002.
- L. Horváth, I. J. Rudas, Modeling and Problem Solving Methods for Engineers, ISBN 0-12-602250-X, Elsevier, Academic Press, New York, etc., 2004

Recommended:

- M. Mortenson, Geometric Modeling, Industrial Press, ISBN-13: 978-0831132989, 2006
- I. Stroud, Boundary Representation Modelling Techniques, Springer, ISBN-13: 978-1846283123, 2006
- L. A. Piegl, The NURBS Book, Springer, ISBN-13: 978-3540615453, 1996

<table>
<tr><td>Name:
Engineering Modeling and Computer Graphics</td><td>NEPTUN-code:
regular: NMVMG1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 1/0/1</td></tr>
<tr><td colspan="2">Credits: 2
Requirement: practice mark</td><td>Prerequisite:
-</td></tr>
</table>

<table>
<tr><td>Responsible:
Laszlo HORVATH</td><td>Position:
full prof</td><td>Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
</table>

Course description

Mathematical representation, analysis, and optimizing for PLM2 paradigm based virtual prototyping. Extended feature driven contextual object definition for complex engineering structures. Topology based definition and recognition of form features in boundary shape representation. Definition and connection of parametric surfaces using generation rules and contextual object parameter relationships. Group definition of complex surfaces using curve network and sculpt curve. Definition of integrated product information model (IPIM) using generic and application resources. Associative definition of adaptive mesh for finite element analysis considering variable mesh density and mesh distortion. Optimization algorithms for decision on engineering objects. Ergonomic analysis of human activity and posture using associative product shape and human (Manikin) representations. Multi axis motion path definition for equipment control in accordance with contextual boundary shape representation.
Changed role of graphics at interactive info-communication between human and model generation procedures. Visualization of 3D shape representation using 2D projection in viewport. Dynamic navigation at interactive graphics assisted virtual object definition. Relating and transformation of model, normalized and screen coordinate systems. Modeling for visualization of parametric surfaces using model of light effect. Linearization of surface descriptions for visualization and rapid prototyping. Channels and actions for position and shape animation of objects in model space. Hair and particle animation. Human interactions in immersive environment (CAVE). Cooperation between virtual and physical spaces (augmented reality). Capture of shape and human motions in virtual world. Control of visual shape recognition by surface model representations.

Literature

Compulsory:

- M. K. Agoston, Computer Graphics and Geometric Modelling: Mathematics, Springer, ISBN-13: 978-1852338176, 2005
- D. R. Ferguson, T. J. Peters, Mathematics for Industry: Challenges and Frontiers : a Process View: Practice and Theory, SIAM, ISBN 0-89871-598-9, 2005

Recommended:

- R. D. Cook, D. S. Malkus, M. E. Plesha, R. J. Witt, Concepts and Applications of Finite Element Analysis, John Wiley & Sons, ISBN: 0-471-35605-0, 2002
- L. Horváth, I. J. Rudas, Modeling and Problem Solving Methods for Engineers, ISBN 0-12-602250-X, Elsevier, Academic Press, New York, etc., 2004

<table>
<tr><td colspan="2">Name:
Decision and Optimization in Power Systems</td><td colspan="2">NEPTUN-code:
regular: NMVDO1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="3">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Peter KADAR</td><td colspan="2">Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="5">Course description</td></tr>
<tr><td colspan="5">Energy application, energy systems, power supply alternatives, life-cycle analysis, externalities, decision spaces, decision trees, expert systems, optimization techniques, linear programming, constraint programming, genetic algorithms, Pareto optimization, strategy making, strategic analysis, energy strategies, power supply security.</td></tr>
<tr><td colspan="5">Literature</td></tr>
<tr><td colspan="5">Compulsory:
• R. Natarajan, Computer-aided Power System Analysis, Marcel Dekker, 2002

Recommended:
• K. Y. Lee, M. A. El-Sharkawi, Modern Heuristic Optimization Techniques, Wiley, 2007
• R. M. Grant, Contemporary strategy analysis, Blackwell, Oxford, 1998
• S. Segal-Horn (ed), The strategy reader, Blackwell, Oxford, 1998</td></tr>
</table>

<table>
<tr><td>Name:
Model-based Problem Solution I</td><td colspan="2">NEPTUN-code:
regular: NIVMP1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 1/1/0</td></tr>
<tr><td colspan="2">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Jozsef TICK</td><td>Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="4" align="center">Course description</td></tr>
<tr><td colspan="4">The seminar goes through the life cycle model of computer-aided problem solving, it focuses on the importance of modeling in development, and gives an introduction to Unified Modeling Language. It covers the UML model types in the course of software development, the relationship among the models, it introduces the Rational Unified Process, software development with RUP support, and the application of CASE tools in case of UML+RUP development, The seminar focuses on typical solutions, practical tasks, analysis of case studies and individual application development.</td></tr>
<tr><td colspan="4" align="center">Literature</td></tr>
<tr><td colspan="4"><u>Compulsory:</u>
Ian Sommerville: Software Engineering (9th Edition), Pearson, 2011.
Hassan Gomaa: Software Modeling and Design - UML, Use Cases, Patterns, and Software Architectures, Cambridge University Press, 2011
<u>Recommended:</u>
Roger S. Pressman: Software Engineering, a practitioner’s approach, 6th Edition, McGraw-Hill, 2005</td></tr>
</table>

Name: **Model-based Problem Solution II**	**_NEPTUN-code:_** regular: NIVMP2PMNE	**_Number of periods/week (lec/sem/lab):_** regular: 1/1/0
Credits: 2 ***Requirement:*** practice mark		***Prerequisite:*** NIVMP1PMNE Model-based Problem Solution I
Responsible: Jozsef TICK	***Position:*** assoc. prof	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Informatics

Course description

The course gives an introduction to the conceptual background and the methodology of Model-Driven Software Development as well as its application possibilities in practice; furthermore beyond the basics of software modeling the course gives an insight into Domain Specific Modeling as well as model transformation possibilities. The course is practice-oriented and deals with practical problems, tasks and case studies to support theoretical knowledge. The seminars are based on problem-based learning and students are trained through individual assignment that they gave to solve using a framework.

Literature

Compulsory:

- Ian Sommerville: Software Engineering (9th Edition), Pearson, 2011.
- Hassan Gomaa: Software Modeling and Design - UML, Use Cases, Patterns, and Software Architectures, Cambridge University Press, 2011

Recommended:

- Roger S. Pressman: Software Engineering, a practitioner's approach, 6th Edition, McGraw-Hill, 2005

Name: Problem solution with computers I	**NEPTUN-code:** regular: NIVPS1PMNE	**Number of periods/week (lec/sem/lab):** regular: 1/1/0
Credits: 2 ***Requirement:*** practice mark	***Prerequisite:*** -	
Responsible: Jozsef TICK	***Position:*** assoc. prof	***Faculty and Institute name:*** John von Neumann Faculty of Informatics Institute of Applied Informatics

Course description

The course covers the model of computer-based problem solving, the components of this model, the data structures, the algorithms, the description formalisms, the present possibilities of conceptualizing algorithms, the procedure of problem solving, the functions of different models, the analysis methods of models, the mapping of models, the procedure and problems of implementation. Furthermore, during the seminar the computer-based language environments, problem solving, the OO philosophy, language constructions, program-libraries, problem solving in OO environment, phases and steps of software development, application development from formulating the problem to program testing, case studies, practical problems and hands-on practices are dealt with.

Literature

Compulsory:

- Ian Sommerville: Software Engineering (9th Edition), Pearson, 2011
- Hassan Gomaa: Software Modeling and Design - UML, Use Cases, Patterns, and Software Architectures, Cambridge University Press, 2011

Recommended:

- Roger S. Pressman: Software Engineering, a practitioner's approach, 6th Edition, McGraw-Hill, 2005

<table>
<tr><td colspan="2">Name:
Problem solution with computers II</td><td colspan="2">NEPTUN-code:
regular: NIVPS2PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 1/1/0</td></tr>
<tr><td colspan="3">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
NIVPS1PMNE Problem solution with computers I</td></tr>
<tr><td>Responsible:
Jozsef TICK</td><td colspan="2">Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="5" align="center">Course description</td></tr>
<tr><td colspan="5">The course deals with computer-aided problem solving in case of complex cases, the partitioning of problems, and software development in case of complex systems. The seminar handles database models, the relationship of the developed application to the database, the use of critical factors in case of databases. It covers the models of web-based applications, their elaboration and development possibilities. The security questions of distributed applications, application development with CASE tools are also covered. The students get an introduction to the component-based philosophy, software development with the use of components, reuse-oriented software development. Students are required to develop a complex application in teams with the help of the learnt solutions.</td></tr>
<tr><td colspan="5" align="center">Literature</td></tr>
<tr><td colspan="5"><u>Compulsory:</u>
Ian Sommerville: Software Engineering (9th Edition), Pearson, 2011.
Hassan Gomaa: Software Modeling and Design - UML, Use Cases, Patterns, and Software Architectures, Cambridge University Press, 2011
<u>Recommended:</u>
Roger S. Pressman: Software Engineering, a practitioner’s approach, 6th Edition, McGraw-Hill, 2005</td></tr>
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<table>
<tr><td colspan="2">Name:
Software development for parallel architectures</td><td colspan="2">NEPTUN-code:
regular: NIVSP1PMNE</td><td>Number of periods/week (lec/sem/lab):
regular: 2/0/2</td></tr>
<tr><td colspan="3">Credits: 4
Requirement: exam</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Zoltan VAMOSSY</td><td colspan="2">Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Informatics</td></tr>
<tr><td colspan="5">Course description</td></tr>
<tr><td colspan="5">Introduction to parallel computing and parallel computer architectures. Parallel algorithm models, programming platforms, processes and threads, threadpools. Synchronization methods (lock, mutex, semaphore) and signaling (barriers). Debugging parallel programs, performance. Principles of parallel algorithm design. Decomposition techniques, agglomeration, mapping methods and load balancing. Parallel programming algorithms. Dense matrix algorithm, sorting, searching. Numerical methods. Search algorithms for discrete optimization, Dynamic programming. Introduction in parallel techniques of image processing. Message-passing programming. Data parallel computing on GPGPU.</td></tr>
<tr><td colspan="5">Literature</td></tr>
<tr><td colspan="5"><u>Compulsory:</u>
A. Grama, A. Gupta, G. Karypis, V. Kumar: Introduction to Parallel Computing, 2nd edition Addison-Wesley, 2003
B. Wilkinson, M. Allen, Parallel Programming, 2nd edition, Prentice Hall, 2005
T. Rauber, G. Rünger, Parallel Programming (For Multicore and Cluster Systems), Springer, 2010
<u>Recommended:</u>
J. Albahari: Threading in C#, http://www.albahari.com/threading/</td></tr>
</table>

Name: **Optimization Models**	**_NEPTUN-code:_** regular: NMVOP1PMNE	**_Number of periods/week (lec/sem/lab):_** regular:0/2/0
Credits: 2 **_Requirement:_** practice mark		**_Prerequisite:_** -
Responsible: Janos FULOP	**_Position:_** assoc. prof	**_Faculty and Institute name:_** John von Neumann Faculty of Informatics Institute of Applied Mathematics

Course description

The aim of the course is to give a brief overview of the basic optimization models, to introduce the students into using computer tools of modelling and solving optimization problems, and to show how to interpret and apply the results. During the course the modelling and solver software GAMS is applied. The students also use GAMS for modelling and solving the optimization problems of homework.

Topics: Practical models of linear optimization. Interpretation of duality and shadow prices. Practical models of integer optimization. The branch-and-bound method. Application of tolerances. Logical constraints in optimization problems. Optimization in networks. The traveling salesman problem. Practical models of nonlinear optimization. Portfolio optimization models. Optimization models of discriminant analysis and clustering. Goal programming. Fractional programming. Data envelopment analysis.

Literature

Compulsory:

- R. Rosenthal: A GAMS Tutorial. http://www.gams.com/dd/docs/gams/Tutorial.pdf
- A. Brooke, D. Kendrick, A. Meeraus, GAMS – A User's Guide, 2014 http://www.gams.com/dd/docs/bigdocs/GAMSUsersGuide.pdf
- W.L. Winston, J.B. Goldberg: Operations Research: Applications and Algorithms, Thomson Brooks/Cole, 2004.

Recommended:

- H.P. Williams, Model Building in Mathematical Programming, Wiley, 1995.
- F.S. Hillier, G.J. Libermann: Introduction to Operations Research, McGraw-Hill, 2005

<table>
<tr><td>Name:
Geometric Modeling</td><td colspan="2">NEPTUN-code:
regular: NMVGM1PMNE</td><td colspan="2">Number of periods/week (lec/sem/lab):
regular: 2/0/0</td></tr>
<tr><td colspan="3">Credits: 2
Requirement: practice mark</td><td colspan="2">Prerequisite:
-</td></tr>
<tr><td>Responsible:
Gyula HERMANN</td><td colspan="2">Position:
assoc. prof</td><td colspan="2">Faculty and Institute name:
John von Neumann Faculty of Informatics
Institute of Applied Mathematics</td></tr>
<tr><td colspan="5">Course description</td></tr>
<tr><td colspan="5">Basic differential geometric. Parametric curves. Physical analogy. Taylor and Hermite interpolation. Repeated linear interpolation as a way to construct curves. Beziér curves and their properties. B-spline curves. Correspondence between Beziér and B-spline representation. Intersection of curves. Offset curves and their approximation. Beziér tensor patches. B-spline surfaces. Offset surfaces. Intersection of planes and surfaces. Intersection curve of surface-surface intersection. Curves on surfaces and offset surfaces. Coons patches.</td></tr>
<tr><td colspan="5">Literature</td></tr>
<tr><td colspan="5"><u>Compulsory:</u>
• N. M. Patrikalakis: Computational geometry
• G. Farin: Curves and Surfaces for Computer Aided Design
• M. Mäntyla, Introduction to Solid Modelling

<u>Recommended:</u>
• H. Prautsch, W Böhm, M Paluszny: Bézier and B spline techniques
• J. Hoschek, D. Lasser, Fundamental of Computer Aided Geometric Design</td></tr>
</table>