## Study plan

## Name of study plan: Aplikované matematicko-stochastické metody

Faculty/Institute/Others: Department: Branch of study guaranteed by the department: Welcome page Garantor of the study branch: Program of study: Applied Mathematical Stochastic Methods Type of study: Follow-up master full-time Required credits: 0 Elective courses credits: 120 Sum of credits in the plan: 120 Note on the plan:

Name of the block: Compulsory courses in the program Minimal number of credits of the block: 0 The role of the block: P

Code of the group: NMSPAMSM1 Name of the group: MDP P\_AMSMN 1st year Requirement credits in the group: Requirement courses in the group: In this group you have to complete at least 9 courses Credits in the group: 0

### Note on the group:

|         | J. 64 p.   |            |         |       |          |      |
|---------|--|------------|---------|-------|----------|------|
| Code    | Name of the course / Name of the group of courses<br>(in case of groups of courses the list of codes of their<br>members)<br>Tutors, authors and guarantors (gar.) | Completion | Credits | Scope | Semester | Role |
| 01MMD   | Mathematical Modelling of Traffic<br>Milan Krbálek Milan Krbálek Milan Krbálek (Gar.)  | Z,ZK       | 5       | 2P+2C |          | Ρ    |
| 01RAD   | Regression Data Analysis<br>Tomáš Hobza, Ji í Franc Ji í Franc Tomáš Hobza (Gar.)  | Z,ZK       | 5       | 2P+2C |          | Ρ    |
| 01SKE   | System Reliability and Clinical Experiments<br>Václav K s Václav K s Václav K s (Gar.)   | KZ         | 3       | 2+0   | L        | Ρ    |
| 01SU2   | Machine Learning 2<br>Filip Šroubek Filip Šroubek (Gar.)   | Z,ZK       | 4       | 2P+2C |          | Ρ    |
| 01TIN   | Information Theory<br>Tomáš Hobza Tomáš Hobza (Gar.)   | ZK         | 2       | 2+0   | z        | Ρ    |
| 01NAH   | Theory of Random Processes<br>Jan Vybíral Jan Vybíral Jan Vybíral (Gar.)   | ZK         | 3       | 3+0   | Z        | Ρ    |
| 01VUAM1 | Research Project 1<br>estmír Burdík estmír Burdík (Gar.)   | Z          | 6       | 0+6   | Z        | Ρ    |
| 01VUAM2 | Research Project 2<br>estmír Burdík estmír Burdík (Gar.)   | KZ         | 8       | 0+8   | L        | Ρ    |
| 01ZLMA  | Generalized Linear Models and Applications<br>Tomáš Hobza Tomáš Hobza Tomáš Hobza (Gar.)   | Z,ZK       | 5       | 2P+2C |          | Ρ    |

#### Characteristics of the courses of this group of Study Plan: Code=NMSPAMSM1 Name=MDP P\_AMSMN 1st year

01MMDMathematical Modelling of TrafficZ,ZK51. Basic mathematical description of vehicular traffic - macroscopic and microscopic quantities, relations between them, fundamental diagram and phase map. 2. Empirical knowledge<br/>about traffic flow - meth-odology of traffic data evaluation, 3s-unification procedure, two-phase theory, three-phase theory, VHM and link to capacity calculations in physics of traffic. 3.<br/>Traffic models - general overview, classification of models, examples, Greenbergs macroscopic model and its solution, Montrolls microscopic model and its solution. 4. Lighthill-Whitham<br/>model - formulation and theoretical solution, Cole-Hopf transformation, formulation of associate Cauchy problem and its solution in distributions, Burgers equation. 5. Cellular traffic<br/>models - Nagel-Schreckenberg model, Fukui-Ischibaschi model, model TASEP and its theoretical solution by MPA. 6. Thermodynamic traffic models - variants, classification by range<br/>and type of potential, Hamiltonian description, general solution methodology, solution of short-range model, connection between thermodynamic models and balance particle systems,<br/>solution of middle-ranged model with logarithmic potential. 7. Vehicular Headway Modeling - an insight into the issue, empirical and theoretical knowledge in a given area, criteria for<br/>admissibility of headway distributions, statistical rigidity and changes in its course, derivation of statistical rigidity for thermodynamic gas. 8. Statistical properties of traffic flow - Poisson<br/>and semi-Poisson mode of transport, supra-random traffic states, their detection.Z,K5

| 01RAD                      | Regression Data Analysis  | Z.ZK                  | 5                 |
|----------------------------|---|-----------------------|-------------------|
| 1.Simple linear regressi   | on: least squares estimation, properties of parameter estimates, hypotheses tests and confi-dence intervals for parameters of the     | he model, model-t     | based prediction, |
| analysis of residuals 2.   | Multiple linear regression: general linear model, least squares estimation, analytical and numerical solutions of the normal eq       | uations, propertie    | s of parameter    |
| estimates, coefficient o   | f determination, F-test, prediction intervals 3.Residuals, diagnostics and transformations: residuals and residual plots, norma       | lity tests, detection | n of outlying and |
| influential observations   | , hat matrix, Cooks distance, transformations of dependent and independent varia-ble, Box-Cox transformation 4. Selection of          | f a regression mod    | del: criteria     |
| functions, R2 statistics,  | Mallows Cp statistics, Akaike and Bayes infor-mation criteria, stepwise regression and backward elimination 5.Multicollineari         | ity: impact of multi  | collinearity on   |
| precision of the parame    | ter estimates, detecting and combatting multicollinearity, ridge regression   |                       |                   |
| 01SKE                      | System Reliability and Clinical Experiments   | KZ                    | 3                 |
| The main goal of the su    | bject is to provide the mathematical principles of reliability theory and techniques of survival data analysis, reliability of compor | nent systems, asy     | mptotic methods   |
| for reliability, concept o | f experiments under censoring and their processing in clinical trials (life-time models). The techniques are illustrated and test     | ed within practical   | examples          |
| originating from lifetime  | material experiments and clinical trials.   |                       |                   |
| 01SU2                      | Machine Learning 2  | Z,ZK                  | 4                 |
| 1.Fundamental topics fr    | om the probability theory and machine learning (classical distributions, Bayes theorem, Kullback-Leibler divergence, curse of di      | mensionality, over    | fitting, maximum  |
| likelihood and maximur     | n a posteriori estimators, Principle Component Analysis) 2.Decision trees: general schema, recursive partitioning, optimal pa         | rtitioning and prur   | ning, ensemble    |
| learning - bagging, boo    | sting, random forests. 3.Examples of decision trees: Adaptive boosting AdaBoost, Gradient boosting, Xgboost. 4.Numerical n            | nethods for optimi    | zation (steepest  |
| descent, conjugate gra     | dient, Newton and quasi-Newton, constrained extrema, Lagrangian). 5.Deep feedforward networks (hidden units, nonlinear a              | ctivation functions   | , output units,   |
| loss functional, stochas   | tic gradient descent, back-propagation algorithm) 6. Optimization for training deep models (regularization, algorithms with adap      | tive learning rates   | 7.Convolutional   |
| neural networks 8.Recu     | urrent neural networks 9.Advanced network architectures (autoencoders, Generative Adversarial networks) 10.Applications o             | f deep learning (c    | lassification,    |
| segmentation, image re     | econstruction)  |                       |                   |
| 01TIN                      | Information Theory  | ZK                    | 2                 |
| Information theory expl    | ores the fundamental limits of the representation and transmission of information. We will focus on the definition and implicati      | ions of (informatio   | n) entropy, the   |
| source coding theorem      | , and the channel coding theorem. These concepts provide a vital background for researchers in the areas of data compressi            | on, signal proces     | sing, controls,   |
| and pattern recognition    |   |                       |                   |
| 01NAH                      | Theory of Random Processes  | ZK                    | 3                 |
| The course is devoted i    | n part to the basic notions of the general theory of random processes and partially to the theory of stationary processes and se      | quences both we       | akly and strongly |
| stationary ones.           |   |                       |                   |
| 01VUAM1                    | Research Project 1  | Z                     | 6                 |
| Research project on the    | e selected topic under the supervision. Supervision and regular checking of the research project under preparation.                   |                       |                   |
| 01VUAM2                    | Research Project 2  | KZ                    | 8                 |
| Research project on the    | e selected topic under the supervision. Supervision and regular checking of the research project under preparation.                   | I                     |                   |
| 01ZLMA                     | Generalized Linear Models and Applications  | Z,ZK                  | 5                 |
| 1.Generalized linear me    | dels: exponential family, regularity conditions, score function. 2.Estimation of parameters: maximum likelihood estimates, nu         | merical methods u     | used for their    |
| calculation, Newton-Ra     | phson, Fisher-scoring algorithm. 3. Testing of models: asymptotic distribution of the score function and the MLE estimates, mode      | els comparisons, r    | esidual analysis, |
| diagnostic of influential  | observations. 4.Analysis of covariance (ANCOVA), general model of analysis of covariance, one factor ANCOVA, multiple co              | mparisons. 5.Mod      | lels for binary   |
| data: logistic model, no   | rmal model, Gumbel model, model parameters interpretation, odds ratio, tests, residuals. 6. Poisson regression: univariate an         | d multivariate Poi    | sson regression,  |
| model parameters inter     | pretation, tests and residuals. 7. Probability models for contingency tables, log-linear models.                                      |                       |                   |
|                            |   |                       |                   |

## Code of the group: NMSPAMSM2

Name of the group: MND P\_AMSMN 2nd year

Requirement credits in the group:

Requirement courses in the group: In this group you have to complete at least 6 courses

## Credits in the group: 0

## Note on the group:

| Note on the gro |  |            |         |       |          |      |
|-----------------|--|------------|---------|-------|----------|------|
| Code            | Name of the course / Name of the group of courses<br>(in case of groups of courses the list of codes of their<br>members)<br>Tutors, authors and guarantors (gar.) | Completion | Credits | Scope | Semester | Role |
| 01ADS           | Applications of Data Science<br>Ji í Franc Ji í Franc Ji í Franc (Gar.)  | KZ         | 4       | 1P+2C |          | Р    |
| 01DPAM1         | Master Thesis 1<br>estmír Burdík estmír Burdík estmír Burdík (Gar.)  | Z          | 10      | 0+10  |          | Ρ    |
| 01DPAM2         | Master Thesis 2<br>estmír Burdík estmír Burdík estmír Burdík (Gar.)  | Z          | 20      | 0+20  |          | Ρ    |
| 18HA            | Heuristic Algorithms<br>Jaromír Kukal Jaromír Kukal Jaromír Kukal (Gar.)   | ZK         | 4       | 2P+2C | L        | Ρ    |
| 01NAEX          | Design of Experiments<br>Jií Franc Ji í Franc Jií Franc (Gar.)   | Z,ZK       | 3       | 2P+1C |          | Ρ    |
| 01DISE          | Diploma Seminar<br>estmír Burdík estmír Burdík estmír Burdík (Gar.)  | Z          | 1       | 0P+2S |          | Р    |
| 01TNM           | Random Matrix Theory<br>Jan Vybíral Jan Vybíral Jan Vybíral (Gar.)   | ZK         | 2       | 2+0   | Z        | Р    |

#### Characteristics of the courses of this group of Study Plan: Code=NMSPAMSM2 Name=MND P\_AMSMN 2nd year

| 01ADS   | Applications of Data Science   | KZ                 | 4                  |  |  |  |
|---|--|--------------------|--------------------|--|--|--|
| Practical application of mathematical modeling methods, statistics and machine learning needs wide range of tasks from data preparation and collection to design of an appropriat |  |                    |                    |  |  |  |
| method and its division   | into units for development and implementation into the production. Last, but not least, the cooperation in group and manager   | ment of a modern   | data project is    |  |  |  |
| crucial. The actual stand   | dard of required tools will be presented on lectures. Further, these procedures will be applied during exercises with an empha | asis on team colla | aboration, project |  |  |  |
| planning. At the end of   | planning. At the end of the course, students will present their results to other teams.  |                    |                    |  |  |  |
| 01DPAM1   | Master Thesis 1  | Z                  | 10                 |  |  |  |
| Master's thesis prepara   | tion.  |                    |                    |  |  |  |

|                                     | Master Thesis 2  | 7                   |                   |
|-------------------------------------|--|---------------------|-------------------|
| 01DPAM2                             | Master Thesis 2  | Z                   | 20                |
| Master's thesis prepara             | tion.  |                     |                   |
| 18HA                                | Heuristic Algorithms   | ZK                  | 4                 |
| Heuristic algorithms of             | potimization operates on discrete or continuous domains. Brutal force, stochastic, greedy, physically, biologically and sociolog       | jically motivated h | euristic are      |
| included, used for optim            | num finding and compared.  |                     |                   |
| 01NAEX                              | Design of Experiments  | Z,ZK                | 3                 |
| 1.Introduction to the de            | sign of experiments and data analysis. 2. Completely randomized one-factor experiment: introduction of a fixed-effect model, 1         | tests of equality o | f mean values,    |
| choice of number of ob              | servations. 3.Methods of multiple comparison: Bonferroni method, Scheffy method, Tukey method 4.Randomized complete bl                 | lock design: mode   | l definition,     |
| equality effects tests, pe          | ower of test, determining sample size. 5. Latin and Greco-Latin squares, balanced incomplete block design, model adequacy              | checking, residua   | ls, multiple      |
| comparisons. 6.Two fac              | or factorial design: statistical models and their properties for designs 2^2, 2^3 and 2^k, fractional factorial design, resolutions. 7 | .3^k factorial desi | gns, confounding  |
| in 3 <sup>k</sup> factorial design. | 3.Models with random effects, factorials with mixed levels.  |                     |                   |
| 01DISE                              | Diploma Seminar  | Z                   | 1                 |
| In the first part of the se         | minar, students familiarize themselves with the general principles of publishing and presenting scientific work and the formal         | requirements for    | diploma projects  |
| at the faculty. The secon           | nd part is designed as a practical training for the defence of the diploma project. The students give oral presentations of the cu     | urrent state of the | research results  |
| achieved during the wo              | rk on their projects. Each presentation is followed by a discussion on scientific matters as well as on the possibilities of impro     | ving the students   | performance.      |
| 01TNM                               | Random Matrix Theory   | ZK                  | 2                 |
| Theory of random matri              | ces appeared first in 60's in the 20th century in connection with statistical physics and the theory of nucleis of atoms of heavy      | metals. The main    | interest of study |
| is the distribution of eige         | envalues of symmetric random matrices. In the 21st century the results of theory of random matrices were applied in theoretic          | al computer scien   | ce and numerics   |
| for design of random al             | gorithms.  |                     |                   |
|                                     |  |                     |                   |

## Name of the block: Compulsory elective courses Minimal number of credits of the block: 0 The role of the block: PV

Code of the group: NMSPAMSMPV1

Name of the group: MDP P\_AMSMN Required optional courses 1st year

Requirement credits in the group:

Requirement courses in the group: In this group you have to complete at least 2 courses Credits in the group: 0

Note on the group:

Studenti si volí alespoň dva předměty z této skupiny, přičemž mezi nimi musí být alespoň jeden z dvojice 01SSI a 01MEU

| Code    | Name of the course / Name of the group of courses<br>(in case of groups of courses the list of codes of their<br>members)<br>Tutors, authors and guarantors (gar.) | Completion | Credits | Scope | Semester | Role |
|---------|--|------------|---------|-------|----------|------|
| 01BAPS  | Bayesian principles in statistics<br>Václav K s Václav K s Václav K s (Gar.)   | ZK         | 3       | 3+0   |          | PV   |
| 01DIZO  | Digital Image Processing<br>Barbara Zitová Barbara Zitová Barbara Zitová (Gar.)  | ZK         | 4       | 2P+2C |          | PV   |
| 01DYNR1 | <b>Dynamic Decision Making 1</b><br>Ta jana Gaj, Miroslav Kárný <b>Ta jana Gaj</b> Ta jana Gaj (Gar.)  | Z,ZK       | 3       | 2P+1C |          | PV   |
| 01MEU   | Modelling Extremal Events<br>Václav K s Václav K s Václav K s (Gar.)   | ZK         | 3       | 2P    |          | PV   |
| 01SSI   | Social Systems and Their Simulations<br>Milan Krbálek, Marek Buká ek Marek Buká ek Milan Krbálek (Gar.)  | KZ         | 4       | 2+1   |          | PV   |

# Characteristics of the courses of this group of Study Plan: Code=NMSPAMSMPV1 Name=MDP P\_AMSMN Required optional courses 1st year

| 01BAPS Bayesian principles in statistics  | ZK                     | 3                   |
|---|------------------------|---------------------|
| The main goal of the subject is to provide decision making mathematical principles with random effects, optimal and robust strategies and their mutual  | al links together wi   | th computational    |
| aspects for the real applications. The techniques are illustrated within practical examples originating from point and interval estimation and statistical  | I hypothesis testin    | ig.                 |
| 01DIZO Digital Image Processing   | ZK                     | 4                   |
| image sampling and quantization, Shannon theorem, aliasing basic image operations, histogram, contrast stretching, noise removal, image sharpen   | ing linear filtering i | n the spatial and   |
| frequency domains, convolution, Fourier transform edge detection, corner detection feature detection image degradations and their modelling, inver  | se and Wiener filte    | ering, restoration  |
| of motion-blurred and out-of-focus blurred images image segmentation mathematical morphology image registration and matching  |                        |                     |
| 01DYNR1 Dynamic Decision Making 1   | Z,ZK                   | 3                   |
| Design, control and analysis of intelligent agents (or systems) that behave appropriately in various circumstances are highly demanded (artificial int  | elligence and mac      | chine learning,     |
| data mining, financial modelling, natural language processing, bioinformatics, web search and information retrieval, algorithm design, system design,   | network analysis,      | and more). Such     |
| intelligent agents need to reason with uncertain information and limited computational resources. Effective decision making requires the knowledge  | about: . the agent'    | 's environment      |
| and its dynamics (including the presence of other intelligent agents), . the agent's goals and preferences . the agent's abilities to observe and influe  | nce the environme      | nt. This course     |
| introduces dynamic decision making under uncertainty and computational methods supporting decision-making. The course helps to develop the material decision making and computational methods supporting decision-making. | athematical reasor     | ning skills crucial |
| for areas inherently involving uncertainty. These skills can serve as the foundation for further study in any application area you choose to pursue an  | d may also help yc     | ou to analyse the   |
| uncertainty in your everyday life. Course objectives: - Learn the basic ideas and techniques underlying design of intelligent rational agents. A specif   | c emphasis will be     | e on the            |
| decision-theoretic modelling paradigm Understand state-of-the-art of decision making (DM) Be able to formulate decision making or learning prob   | lem and select app     | propriate method    |
| for a given task/application Be able to understand research papers in the field (main conferences: IJCAI, NeurIPS, AAMAS, ICAART, ICM; main jc  | urnals: AI, JAIR, J    | JAAMAS, IJAR).      |
| - Try out some ideas of your own.   |                        |                     |

| odelling Extremal Events  |  |  | 1  | 1  | 3  |
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|   |  |  |  |  |  |
| cial Systems and Their Simulations  |  |  |  | KZ   | 4  |
| issue of social systems modeling. That includes stochastic methods and methods of     | statistical physics  | for descripti  | on and ana   | lytical solutior   | of social  |
| entation of particular models and comparison of the computer simulations results with | the empirical data   | a.   |  |  |  |
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| o: NMSPAMSMPV2  |  |  |  |  |  |
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|   | u year   |  |  |  |  |
| dits in the group:  |  |  |  |  |  |
| rses in the group: In this group you have to compl                                    | ete at least   | t 2 coui   | ses  |  |  |
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|   | Completion   | Credits  | Scope  | Semester   | Role   |
|   |  |  |  |  |  |
|   | K7   | 4  | 10.20  |  | PV   |
| Ji í Franc <b>Ji í Franc</b> Ji í Franc (Gar.)  | Γ.Ζ.   | 4  | 16+20  |  | PV   |
| Data science  | KZ   | 3  | 1P+2C  |  | PV   |
|   |  |  |  |  |  |
|   | ZK   | 2  | 2P+0C  | Z  | PV   |
|   |  |  |  |  |  |
| Tomáš Hobza, Jan Amos Víšek <b>Jan Amos Víšek</b> Jan Amos Víšek (Gar.)               | ∠K   | 2  | 22   |  | PV   |
|   | uter nets, possible admission control, machine learning, on-off approximation. 2.Distri<br>ensity estimators and their tails, asymptotic properties, MISE optimality. 4.Semiparama<br>, properties, Kolmogorov entropy, Vapnik-Chervonenkis dimension, application. 6.Fluc<br>d central limit theorem, domains of attraction, sub-exponential distributions. 8.Heavy-te.<br>9.Return period of (insurance) events, record counting process, Gumbel method of<br>ain of attraction. 11.Generalized extreme value distribution, generalized Pareto distribu-<br>timator of quantile, application. 13.Applications to real data from hydrology, geology, in<br>cial Systems and Their Simulations<br>issue of social systems modeling. That includes stochastic methods and methods of<br>entation of particular models and comparison of the computer simulations results with<br>p: NMSPAMSMPV2<br>mp: MDP P_AMSMN Required optional courses 2nd<br>dits in the group:<br>rses in the group: In this group you have to compl-<br>up: 0<br>p: Student si volí povinně alesp<br>Name of the course / Name of the group of courses<br>( <i>in case of groups of courses the list of codes of their<br/>members</i> )<br>Tutors, authors and guarantors (gar.)<br>Applications of Data Science<br>Ji í Franc Ji í Franc Ji í Franc (Gar.)<br>Financial and Insurance Mathematics<br>Joel Horowitz Joel Horowitz Joel Horowitz (Gar.)<br>Advanced and Robust Regression Models | uter nets, possible admission control, machine learning, on-off approximation. 2.Distribution-free inequa<br>ansity estimators and their tails, asymptotic properties, MISE optimality. 4.Semiparametric estimation, re<br>properties, Kolmogorov entropy, Vapnik-Chervonenkis dimension, application. 6.Fluctuation of random<br>d central limit theorem, domains of attraction, sub-exponential distributions. 8.Heavy-tail distribution det<br>a.9.Return period of (insurance) events, record counting process, Gumbel method of exceedance. 10.F<br>ain of attraction. 11.Generalized extreme value distribution, generalized Pareto distribution, properties a<br>timator of quantile, application. 13.Applications to real data from hydrology, geology, insurance, finance,<br>cial Systems and Their Simulations<br>issue of social systems modeling. That includes stochastic methods and methods of statistical physics<br>entation of particular models and comparison of the computer simulations results with the empirical date<br>to: NMSPAMSMPV2<br>up: MDP P_AMSMN Required optional courses 2nd year<br>dits in the group: In this group you have to complete at leas:<br>up: 0<br>p: Student si volí povinně alespoň dva předr<br>( <i>in case of groups of courses the list of codes of their<br/>members</i> )<br>Tutors, authors and guarantors (gar.)<br>Applications of Data Science<br><i>Ji í Franc Ji í Franc Ji í Franc (Gar.</i> )<br>KZ<br>Financial and Insurance Mathematics<br><i>Joel Horowitz Joel Horowitz (Gar.</i> )<br>Advanced and Robust Regression Models<br>7K | uter nets, possible admission control, machine learning, on-off approximation. 2.Distribution-free inequalities for tail<br>ansity estimators and their tails, asymptotic properties, MISE optimality. 4.Semiparametric estimation, retransformed<br>properties, Kolmogorov entropy, Vapnik-Chervonenkis dimension, application. 6.Fluctuation of random sums, stabil<br>d central limit theorem, domains of attraction, sub-exponential distributions. 8.Heavy-tail distribution detections, PP :<br>a. 9.Return period of (insurance) events, record counting process, Gumbel method of exceedance. 10.Fluctuation of<br>ain of attraction. 11.Generalized extreme value distribution, generalized Pareto distribution, properties and utilization<br>imator of quantile, application. 13.Applications to real data from hydrology, geology, insurance, finance, numerous of<br>cial Systems and Their Simulations<br>issue of social systems modeling. That includes stochastic methods and methods of statistical physics for descripti-<br>entation of particular models and comparison of the computer simulations results with the empirical data.<br>D: NMSPAMSMPV2<br>pp: MDP P_AMSMN Required optional courses 2nd year<br>dits in the group: In this group you have to complete at least 2 court<br>up: 0<br>p: Student si volí povinně alespoň dva předměty z té<br>Name of the course / Name of the group of courses<br>( <i>in case of groups of courses the list of codes of their<br/>members</i> )<br>Tutors, authors and guarantors (gar.)<br>Applications of Data Science<br>Ji í Franc Ji í Franc Ji í Franc (Gar.)<br>Financial and Insurance Mathematics<br>Joel Horowitz Joel Horowitz (Gar.)<br>Advanced and Robust Regression Models<br>Tuto 2 and Robust Regression Models | uter nets, possible admission control, machine learning, on-off approximation. 2.Distribution-free inequalities for tail probability<br>ensity estimators and their tails, asymptotic properties, MISE optimality. 4.Semiparametric estimation, retransformed densities,<br>, properties, Kolmogorov entropy, Vapnik-Chervonenkis dimension, application. 6.Fluctuation of random sums, stable and -stat<br>d central limit theorem, domains of attraction, sub-exponential distributions. 8.Heavy-tail distribution detections, PP and QQ plo<br>e. 9.Return period of (insurance) events, record counting process, Gumbel method of exceedance. 10.Fluctuation of random main<br>ain of attraction. 11.Generalized extreme value distribution, generalized Pareto distribution, properties and utilization. 12.Estima<br>imator of quantile, application. 13.Applications to real data from hydrology, geology, insurance, finance, numerous other examp<br>cial Systems and Their Simulations<br>issue of social systems modeling. That includes stochastic methods and methods of statistical physics for description and ana<br>entation of particular models and comparison of the computer simulations results with the empirical data. | uter neiš, possible admission control, machine learning, on-off approximation. 2.Distribution-free inequalities for tail probability estimation, PC ansity estimators and their tails, asymptotic properties, MISE optimality. 4.Semiparametric estimation, retransformed densities, statistical prog , properties, Kolmogorov entropy, Vapnik-Chervonenkis dimension, application. 6.Fluctuation of random sums, stable and -stable distribution of central limit theorem, domains of attraction, sub-exponential distributions. 8.Heavy-tail distribution detections, PP and QQ plots, Mean Exc & a. 9.Return period of (insurance) events, record counting process, Gumbel method of exceedance. 10.Fluctuation of random maxima, Fisher-<br>ain of attraction. 11.Generalized extreme value distribution, generalized Pareto distribution, properties and utilization. 12.Estimates of exceed<br>inator of quantile, application. 13.Applications to real data from hydrology, geology, insurance, finance, numerous other examples.<br>cial Systems and Their Simulations KZ   KZ   KZ   KZ   KZ   KZ   KZ   KZ |

#### Characteristics of the courses of this group of Study Plan: Code=NMSPAMSMPV2 Name=MDP P\_AMSMN Required optional courses 2nd year

ΖK

2

2+0

L

Special Functions and Transformations in Image Analysis Jan Flusser Jan Flusser Jan Flusser (Gar.)

ΡV

| 01ADS                    | Applications of Data Science  | KZ                 | 4                   |
|--------------------------|---|--------------------|---------------------|
| Practical application of | mathematical modeling methods, statistics and machine learning needs wide range of tasks from data preparation and collect          | ction to design of | an appropriate      |
| method and its division  | into units for development and implementation into the production. Last, but not least, the cooperation in group and manager        | ment of a modern   | data project is     |
| crucial. The actual stan | dard of required tools will be presented on lectures. Further, these procedures will be applied during exercises with an empha      | asis on team colla | boration, project   |
| planning. At the end of  | the course, students will present their results to other teams.   |                    |                     |
| 01DAS                    | Data science  | KZ                 | 3                   |
| Practical application of | mathematical modeling methods, statistics and machine learning needs wide range of tasks from data preparation and colle            | tion to design of  | an appropriate      |
| method and its division  | into units for development and implementation into the production. Last, but not least, the cooperation in group and manager        | ment of a modern   | data project is     |
| crucial. The actual stan | dard of required tools will be presented on lectures. Further, these procedures will be applied during exercises with an empha      | asis on team colla | boration, project   |
| planning. At the end of  | the course, students will present their results to other teams.   |                    |                     |
| 01FIMA                   | Financial and Insurance Mathematics   | ZK                 | 2                   |
| This course is an introd | uction to the problems of life and non-life insurance and financial mathematics.  | •                  |                     |
| 01PRR                    | Advanced and Robust Regression Models   | ZK                 | 2                   |
| 1.Introduction to robust | regression - M-estimates, qualitative and quantitative robustness, influential functions, outliers, leverage points. 2. The least r | nedian of squares  | s, the trimmed      |
| least squares and the le | east trimmed squares. 3.Weighted least squares and least weighted squares, algorithms, applications. 4.Instrumental weighted        | variables and the  | ir robustification. |
| 5.AR, MA, AR (I) MA, in  | vertibility and stationarity condition. Smoothing of trend using curves, moving averages and exponential. Seasonal and cyclic       | components, tests  | s of randomness,    |
| disturbance (Prais-Wins  | sten, Cochrane-Orcutt). 6. Introduction to mixed linear models, estimation of parameters (ML, REML), generalized mixed linear m     | odels. 7. Repeated | d measurements,     |
| Longitudinal data, corre | ation structure in data. 8. Philosophical debate on mathematical modeling and regression analysis.                                  |                    |                     |
| 01SFTO                   | Special Functions and Transformations in Image Analysis   | ZK                 | 2                   |
| The course broadens to   | pics of the courses ROZ1 and ROZ2. Main attention will be paid to several special functions and transformations (especially         | moment function    | s and wavelet       |
| transform) and their use | e in selected tasks of image processing - edge detection, noise removal, recognition of deformed objects, image registration,       | image compressi    | on, etc. Both the   |
| theory and practical ap  | plications will be discussed.   |                    |                     |
|                          |   |                    |                     |
|                          | la alu. Ele atives a avues a a  |                    |                     |

Name of the block: Elective courses Minimal number of credits of the block: 0 The role of the block: V

01SFTO

Code of the group: NMSPAMSMV Name of the group: MDP P\_AMSMN Optional courses Requirement credits in the group: Requirement courses in the group: Credits in the group: 0

#### Note on the group: Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their Code Completion Credits Scope Semester Role members) Tutors, authors and guarantors (gar.) Analysis and Processing of Diagnostic Signals Zden k P evorovský Zden k P evorovský Zden k P evorovský (Gar.) 01ZASIG ΖK 3 3+0 V Matlab Applications 18AMTL ΚZ 4 2P+2C L V Jaromír Kukal SQL Applications 18SQL Ζ 2 Ζ 0+2 v Jaromír Kukal, Dana Majerová **Dana Majerová** Jaromír Kukal(Gar.) **Applied Data Analysis** 18AAD Ζ 3 1P+1C L Jaromír Kukal, Tomáš Hubínek, Karel Šimánek Jaromír Kukal Jaromír Kukal V (Gar.) **Business Intelligence** 18BI ΚZ 2 1P+1C Ζ V Jaromír Kukal, Matej Mojzeš Jaromír Kukal **Dynamic Decision Making 2** 01DRO2 ΖK 2 2+0v Ta jana Gaj, Miroslav Kárný **Miroslav Kárný** Miroslav Kárný (Gar.) **Hierarchical Bayesian Models** 01HBM ΚZ 2 2+0V Václav Šmídl Václav Šmídl Václav Šmídl (Gar.) Internet and classification methods 01IKLM 2 2P+0C Z,ZK V Martin Hole a Martin Hole a Martin Hole a (Gar.) Compressed Sensing Jan Vybíral Jan Vybíral (Gar.) 01KOS 2 Ζ ΖK 2+0 v Mathematical Modelling of Non-linear Systems 01MMNS 3 1P+1C Ζ ΖK V Michal Beneš Michal Beneš Michal Beneš (Gar.) Mathematical techniques in biology and medicine 01MBM 3 L Z,ZK 2+1 V Václav Klika Václav Klika Václav Klika (Gar.) **Monte Carlo Method** 18MEMC Z,ZK 4 2P+2C Ζ V Jaromír Kukal, Miroslav Virius Miroslav Virius Miroslav Virius (Gar.) **Nonlinear Optimization** 01NELO ΖK 4 3P+0C V Radek Fu ik Radek Fu ik Radek Fu ik (Gar.) **Neural Networks and their Applications 1** 2 01NEUR1 ΖK 2+0 v Martin Hole a, František Hakl František Hakl František Hakl (Gar.) **Probabilistic Models of Artificial Intelligence** 01UMIN ΚZ 2 2+0 Ζ V Ji ina Vejnarová Ji ina Vejnarová Ji ina Vejnarová (Gar.) **Problem Seminar in Mathematical Analysis** 01PSM1 Ζ 2 0P+2S Ζ V Mat j Tušek Mat j Tušek (Gar.) **Problem Seminar in Mathematical Analysis 2** Ζ 01PSM2 2 2S V Mat j Tušek Mat j Tušek (Gar.) Seminar Course on Dynamic Decision Making Ζ 2 01DROS 0+2 v Ta jana Gaj Ta jana Gaj (Gar.) Start-up Project 01SUP 2 ΚZ 2P+0C v P emysl Rubeš P emysl Rubeš P emysl Rubeš (Gar.) Stochastic Differential Equations 2 01SDR ΖK 2P+0C v Michal Beneš Michal Beneš Michal Beneš (Gar.) Student's Scientific Conference 01SVK 5 dní Ζ 1 v Ji í Mikyška Ji í Mikyška (Gar.) Student's seminar in mathematics 1 01SMS1 Ζ 2 0P+2C v Václav Klika Václav Klika (Gar.) Student's seminar in mathematics 2 Ζ 2 0P+2C L 01SMS2 v Václav Klika Václav Klika (Gar.) Theoretical Fundamentals of Neural Networks 01NEUR2 ΖK 3 2+0v Martin Hole a Martin Hole a Martin Hole a (Gar.) Financial Markets Theory Nichita Vatamaniuc, Quang Van Tran Quang Van Tran Quang Van Tran 18TFT ΚZ 4 2P+2C Ζ v (Gar.) Graph Theory Jan Volec, Petr Ambrož Petr Ambrož (Gar.) 01TG ΖK 5 4P+0C V Game Theory Jan Volec Jan Volec (Gar.) 01TEH ΖK 2 2+0 L V **Financial Markets Data Processing** 18ZDFT ΚZ 4 2P+2C L v Quang Van Tran Quang Van Tran Quang Van Tran (Gar.) Characteristics of the courses of this group of Study Plan: Code=NMSPAMSMV Name=MDP P\_AMSMN Optional courses

| 01ZASIG   | Analysis and Processing of Diagnostic Signals  | ZK                | 3                 |  |  |
|---|--|-------------------|-------------------|--|--|
| Digital signal process  | ng, signal transformations and filtrations, spectral and time-frequency analysis   |                   |                   |  |  |
| 18AMTL  | Matlab Applications  | KZ                | 4                 |  |  |
| Systematic application  | n of Matlab optimization toolbox for the solution of linear, quadratic, binary, integer an nonlinear programming tasks. Simulatior | of chaotic system | ns an fractal set |  |  |
| generation. Analysis of   | f trajectories, attractors and fractal sets including estimation of their properties.  |                   |                   |  |  |
| 18SQL   | SQL Applications   | Z                 | 2                 |  |  |
| Practical realization o   | database system according to general principles of database analysis.  |                   |                   |  |  |
| 18AAD   | Applied Data Analysis  | Z                 | 3                 |  |  |
| A practically focused subject that guides you through the topics of Big Data, neural networks, parallel computing, graph analysis, cloud technologies, deployment, and development of |  |                   |                   |  |  |
| software or IoT solution  | ons.   |                   |                   |  |  |

| 18BI  | Business Intelligence   | KZ  | 2   |
|---|---|---|---|
|   | s to explain to the students different characteristics of production and analytical databases and a set of processes, know-hov  | v and tools (not or   | nly) to support   |
| decision-making activiti  | es within the organization. In addition to the basic concept of BI, listeners will get acquainted with the general methodology of im  | plementation of cu  | istom algorithms  |
| derived from other theo   | ries and subjects into the BI environment.  |   |   |
| 01DRO2  | Dynamic Decision Making 2   | ZK  | 2   |
| 1.Overview of the formation   | lised decision-making task and tools for its solution 2. Application of the general fully probabilistic design of decision-making   | strategies for Mar  | kov chains and  |
|   | 3. Aproximation and completion of probabilities serving to processing data-based as well as probabilistic knowledge and pre   |   |   |
|   | -participants decision making and its formalisation 5. Usability of general tools for knowledge sharing and cooperation within mu   | Iltiple-participants  | decision making   |
|   | s of solving decision-making tasks 7.0pen decision-making problems  |   |   |
| 01HBM   | Hierarchical Bayesian Models  | KZ  | 2   |
|   | eory, linear regression, signal separation, mixture models, Bayesian filtering  |   |   |
| 01IKLM  | Internet and classification methods   | Z,ZK  | 2   |
|   | he students get acquainted with classification methods used in three important internet or general-network applications: spar   |   |   |
|   | systems. However, they learn more than only how classification is performed when facing these three problems. On the back   | -   |   |
|   | view about the fundamentals of classification methods. The course is taught in a 2-week cycle, always a 2h lecture and a 2h   |   |   |
| 01KOS   | Compressed Sensing  | ZK  | 2   |
|   | the basic concepts of the theory of compressed sensing an area founded in 2006 in the works of D. Donoho, E. Candes, and T  | -   |   |
| -   | ons of underdetermined systems of linear equations. Due to the applications of sparse representations in electric engeneering   |   |   |
|   | ny different fields. After the first survey lecture, we will study the mathematical foundations of the theory. We prove general NI  |   |   |
|   | ems of linear equations. We introduce conditions which ensure also existence of more effective solvers and show, that these   |   | -   |
|   | ces. As an effective solution method, we will analyze I1-minimization and Orthogonal Matching Pursuit. We will also study stabi<br>he corruption of measurements and the optimality of the results.   | inty and robustnes  | s of the obtained   |
| · · ·   |   | 71/   | 2   |
| 01MMNS  | Athematical Modelling of Non-linear Systems basic terms and results of the theory of finite- and infinitedimensional dynamical systems generated by evolutionary different  | ZK  | 3<br>description of   |
|   |   | -   | description of  |
|   | Second part is devoted to the explanation of basic results of the fractal geometry dealing with attractors of such dynamical s  |   | 0   |
| 01MBM   | Mathematical techniques in biology and medicine   | Z,ZK  | 3   |
|   | nodels; enzyme kinetics; excitable system; reaction-diffusion equations; travelling waves; pattern formation; conditions for Turi   | ing instability, the  | effect of domain  |
|   | bility in PDEs, spectrum of a linear operator, semigroups.  |   |   |
| 18MEMC  | Monte Carlo Method  | Z,ZK  | 4   |
|   | o the numerical method Monte Carlo and to its selected applications.  |   |   |
| 01NELO  | Nonlinear Optimization  | ZK  | 4   |
|   | problems find their application in may areas of applied mathematics. The lecture covers the basics of mathematical programmin   | ng theory with emp  | hasis on convex   |
| optimization and basic  | nethods for unconstrained and constrained optimization. The lecture is supplemented by illustrative examples.   |   |   |
| 01NEUR1   | Neural Networks and their Applications 1  | ZK  | 2   |
| Keywords: Neural netwo  | prks, data separation, functional approximation, supervised learning  |   |   |
|   |   |   |   |
| 01UMIN  | Probabilistic Models of Artificial Intelligence   | KZ  | 2   |
|   | Probabilistic Models of Artificial Intelligence<br>o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-c   |   |   |
|   | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-c  |   |   |
| The course is devoted t   | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-c  |   | _   |
| The course is devoted to particularly to Bayesian 01PSM1  | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-c<br>networks.   | alled graphical Ma  | arkov models,   |
| The course is devoted to<br>particularly to Bayesian<br>01PSM1<br>This course is a semina   | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-c<br>networks.<br>Problem Seminar in Mathematical Analysis   | alled graphical Ma  | arkov models,   |
| The course is devoted to<br>particularly to Bayesian<br>01PSM1<br>This course is a semina   | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-<br>networks.<br>Problem Seminar in Mathematical Analysis<br>r in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in   | alled graphical Ma  | arkov models,   |
| The course is devoted to<br>particularly to Bayesian<br>01PSM1<br>This course is a semina<br>but students will be ass<br>01PSM2   | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-<br>networks.<br>Problem Seminar in Mathematical Analysis<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is  | alled graphical Ma  | arkov models,<br>2<br>re are no exams<br>2  |
| The course is devoted to<br>particularly to Bayesian<br>01PSM1<br>This course is a semina<br>but students will be ass<br>01PSM2<br>This course is a semina  | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-<br>networks.<br>Problem Seminar in Mathematical Analysis<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>Problem Seminar in Mathematical Analysis 2  | alled graphical Ma  | arkov models,<br>2<br>re are no exams<br>2  |
| The course is devoted to<br>particularly to Bayesian<br>01PSM1<br>This course is a semina<br>but students will be ass<br>01PSM2<br>This course is a semina  | o the survey of methods used for uncertainty processing in the field of artificial intelligence. The main attention is paid to so-c<br>networks.<br>Problem Seminar in Mathematical Analysis<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>Problem Seminar in Mathematical Analysis 2<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is  | alled graphical Ma  | arkov models,<br>2<br>re are no exams<br>2  |
| The course is devoted to<br>particularly to Bayesian<br>01PSM1<br>This course is a semina<br>but students will be ass<br>01PSM2<br>This course is a semina<br>but students will be ass<br>01DROS  | o the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-<br>networks.  Problem Seminar in Mathematical Analysis<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>Problem Seminar in Mathematical Analysis 2<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>Seminar Course on Dynamic Decision Making   | alled graphical Ma<br>Z<br>nvited quests. The<br>mandatory.<br>Z<br>nvited quests. The<br>mandatory.<br>Z   | arkov models,<br>2<br>re are no exams<br>2<br>re are no exams<br>2<br>2   |
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| The course is devoted to<br>particularly to Bayesian<br>01PSM1<br>This course is a semina<br>but students will be ass<br>01PSM2<br>This course is a semina<br>but students will be ass<br>01DROS<br>The seminar is devoted<br>01DRO1, in particular for<br>A sub-selection of relevance   | o the survey of methods used for uncertainty processing in the field of artificial intelligence. The main attention is paid to so-<br>networks.  Problem Seminar in Mathematical Analysis<br>ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>Problem Seminar in Mathematical Analysis 2<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>Problem Seminar in Mathematical Analysis 2<br>Ir in advanced mathematical analysis and its applications. Seminar talks will be delivered by students, department staff, and in<br>igned by some homework and they will give at least one talk per semester. The seminar is held in English and attendance is<br>Seminar Course on Dynamic Decision Making<br>to the actual topics and trends in decision making, machine learning (ML) and artificial intelligence (AI). It will extend the top<br>promalisation of DM problem and its solution incl. techniques to tackle the problem; multi-agent DM and related tasks incl. pos<br>ant articles presented at the main DM, ML and AI conferences will be discussed.  | alled graphical Ma<br>Z<br>nvited quests. The<br>mandatory.<br>Z<br>nvited quests. The<br>mandatory.<br>Z<br>ics learned in the   | arkov models,<br>2<br>re are no exams<br>2<br>re are no exams<br>2<br>lecture course  |
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| 18ZDFT                   | Financial Markets Data Processing   | KZ                  | 4              |
|--------------------------|---|---------------------|----------------|
| The course enables stu   | dents to combine knowledge of numerical methods, Matlab programming and financial mathematics to solve practical proble         | ms in finance suc   | h as portfolio |
| optimization, risk manag | gement and valuation of financial derivatives, especially options of different types. Upon completion of the course the student | will be able to for | mulate and     |
| numerically solve concr  | ete problems in the given field and subsequently implement their solutions in practice.   |                     |                |

## List of courses of this pass:

| Code   | Name of the course  | Completion               | Credits       |  |  |  |
|--|---|--------------------------|---------------|--|--|--|
| 01ADS  | Applications of Data Science  | KZ                       | 4             |  |  |  |
| Practical application of mathematical modeling methods, statistics and machine learning needs wide range of tasks from data preparation and collection to design of an appropriate   |   |                          |               |  |  |  |
| method and its division into units for development and implementation into the production. Last, but not least, the cooperation in group and management of a modern data project is crucial. The actual standard of required tools will be presented on lectures. Further, these procedures will be applied during exercises with an emphasis on team collaboration, project |   |                          |               |  |  |  |
| 01BAPS   | planning. At the end of the course, students will present their results to other teams.<br>Bayesian principles in statistics  | ZK                       | 3             |  |  |  |
|  | e subject is to provide decision making mathematical principles with random effects, optimal and robust strategies and their mutual lin   |                          | -             |  |  |  |
| -  | the real applications. The techniques are illustrated within practical examples originating from point and interval estimation and statist  | -                        | -             |  |  |  |
| 01DAS  | Data science  | KZ                       | 3             |  |  |  |
| Practical application  | on of mathematical modeling methods, statistics and machine learning needs wide range of tasks from data preparation and collection   | on to design of an a     | appropriate   |  |  |  |
|  | ision into units for development and implementation into the production. Last, but not least, the cooperation in group and management   |                          |               |  |  |  |
| crucial. The actual  | standard of required tools will be presented on lectures. Further, these procedures will be applied during exercises with an emphasis   | on team collabora        | tion, project |  |  |  |
| 04 DIOF  | planning. At the end of the course, students will present their results to other teams.   | 7                        | -             |  |  |  |
| 01DISE   | Diploma Seminar<br>ne seminar, students familiarize themselves with the general principles of publishing and presenting scientific work and the formal req  | Z<br>Uirements for diplo |               |  |  |  |
|  | econd part is designed as a practical training for the defence of the diploma project. The students give oral presentations of the current  |                          |               |  |  |  |
| -  | ne work on their projects. Each presentation is followed by a discussion on scientific matters as well as on the possibilities of improvir  |                          |               |  |  |  |
| 01DIZO   | Digital Image Processing  | ZK                       | 4             |  |  |  |
| image sampling an  | d quantization, Shannon theorem, aliasing basic image operations, histogram, contrast stretching, noise removal, image sharpening li  | inear filtering in the   | spatial and   |  |  |  |
| frequency domains  | , convolution, Fourier transform edge detection, corner detection feature detection image degradations and their modelling, inverse a   | -                        | , restoration |  |  |  |
|  | of motion-blurred and out-of-focus blurred images image segmentation mathematical morphology image registration and matc  | -                        |               |  |  |  |
| 01DPAM1  | Master Thesis 1   | Z                        | 10            |  |  |  |
|  | Master's thesis preparation.  |                          |               |  |  |  |
| 01DPAM2  | Master Thesis 2   | Z                        | 20            |  |  |  |
|  | Master's thesis preparation.  |                          |               |  |  |  |
| 01DRO2   | Dynamic Decision Making 2   | ZK                       | 2             |  |  |  |
|  | formalised decision-making task and tools for its solution 2.Application of the general fully probabilistic design of decision-making stra<br>models 3.Aproximation and completion of probabilities serving to processing data-based as well as probabilistic knowledge and prei  | -                        |               |  |  |  |
|  | nulti-participants decision making and its formalisation 5. Usability of general tools for knowledge sharing and cooperation within multipl   |                          |               |  |  |  |
|  | 6.Illustrative case studies of solving decision-making tasks 7.Open decision-making problems  |                          | oloninalang   |  |  |  |
| 01DROS   | Seminar Course on Dynamic Decision Making   | Z                        | 2             |  |  |  |
|  | voted to the actual topics and trends in decision making, machine learning (ML) and artificial intelligence (AI). It will extend the topics   | learned in the lect      | 1             |  |  |  |
| 01DRO1, in partice   | lar formalisation of DM problem and its solution incl. techniques to tackle the problem; multi-agent DM and related tasks incl. possible  | e ways of agents?        | interaction.  |  |  |  |
|  | A sub-selection of relevant articles presented at the main DM, ML and AI conferences will be discussed.   |                          |               |  |  |  |
| 01DYNR1  | Dynamic Decision Making 1   | Z,ZK                     | 3             |  |  |  |
| -  | ad analysis of intelligent agents (or systems) that behave appropriately in various circumstances are highly demanded (artificial intelli   | -                        | -             |  |  |  |
| -  | ial modelling, natural language processing, bioinformatics, web search and information retrieval, algorithm design, system design, network of the second s   |                          | -             |  |  |  |
|  | need to reason with uncertain information and limited computational resources. Effective decision making requires the knowledge about<br>including the presence of other intelligent agents), . the agent's goals and preferences . the agent's abilities to observe and influence  | -                        |               |  |  |  |
|  | c decision making under uncertainty and computational methods supporting decision-making. The course helps to develop the mather  |                          |               |  |  |  |
| -  | r involving uncertainty. These skills can serve as the foundation for further study in any application area you choose to pursue and ma   | -                        |               |  |  |  |
| uncertainty in   | your everyday life. Course objectives: - Learn the basic ideas and techniques underlying design of intelligent rational agents. A specif  | ic emphasis will be      | on the        |  |  |  |
| decision-theoretic r   | nodelling paradigm Understand state-of-the-art of decision making (DM) Be able to formulate decision making or learning problem   | and select appropr       | iate method   |  |  |  |
| for a given task/ap  | plication Be able to understand research papers in the field (main conferences: IJCAI, NeurIPS, AAMAS, ICAART, ICM; main journation of the second se | als: AI, JAIR, JAAN      | /IAS, IJAR).  |  |  |  |
|  | - Try out some ideas of your own.   |                          |               |  |  |  |
| 01FIMA   | Financial and Insurance Mathematics   | ZK                       | 2             |  |  |  |
| 0411514  | This course is an introduction to the problems of life and non-life insurance and financial mathematics.  | 1/7                      |               |  |  |  |
| 01HBM  | Hierarchical Bayesian Models  | KZ                       | 2             |  |  |  |
|  | Keywords: Bayesian theory, linear regression, signal separation, mixture models, Bayesian filtering   | 7 71/                    | 0             |  |  |  |
| 01IKLM   | Internet and classification methods   | Z,ZK                     | 2             |  |  |  |
| Attending the course, the students get acquainted with classification methods used in three important internet or general-network applications: spam filtering, recommender systems, and intrusion detection systems. However, they learn more than only how classification is performed when facing these three problems. On the background of the above applications,      |   |                          |               |  |  |  |
| they get an overall overview about the fundamentals of classification methods. The course is taught in a 2-week cycle, always a 2h lecture and a 2h practice at computer labs.   |   |                          |               |  |  |  |
| 01KOS  | Compressed Sensing  | ZK                       | 2             |  |  |  |
|  | ntroduce basic concepts of the theory of compressed sensing an area founded in 2006 in the works of D. Donoho, E. Candes, and T.  |                          | 1             |  |  |  |
|  | olutions of underdetermined systems of linear equations. Due to the applications of sparse representations in electric engeneering and  | -                        |               |  |  |  |
| was quickly used in many different fields. After the first survey lecture, we will study the mathematical foundations of the theory. We prove general NP-completeness of the search for  |   |                          |               |  |  |  |
| sparse solutions of systems of linear equations. We introduce conditions which ensure also existence of more effective solvers and show, that these are satisfied for example for  |   |                          |               |  |  |  |

Gaussian random matrices. As an effective solution method, we will analyze I1-minimization and Orthogonal Matching Pursuit. We will also study stability and robustness of the obtained results with respect to the corruption of measurements and the optimality of the results.

| results with respect to the corruption of measurements and the optimality of the results.  |  |   |  |  |  |
|--|--|---|--|--|--|
| 01MBM Mathematical techniques in biology and medicine  | Z,ZK   | 3   |  |  |  |
| Spatially independent models; enzyme kinetics; excitable system; reaction-diffusion equations; travelling waves; pattern formation; conditions for Turing  | nstability, the effect   | of domain   |  |  |  |
| size; the concept of stability in PDEs, spectrum of a linear operator, semigroups.   |  |   |  |  |  |
| 01MEU Modelling Extremal Events  | ZK   | 3   |  |  |  |
| 1.Aggregated traffic in computer nets, possible admission control, machine learning, on-off approximation. 2.Distribution-free inequalities for tail probability   | ility estimation, PC   | simulation  |  |  |  |
| of traffic. 3. Nonparametric density estimators and their tails, asymptotic properties, MISE optimality. 4. Semiparametric estimation, retransformed densitie  | es, statistical proper   | rties, score  |  |  |  |
| functions. 5. Phi-divergences, properties, Kolmogorov entropy, Vapnik-Chervonenkis dimension, application. 6. Fluctuation of random sums, stable and   | -stable distribution   | ns, their   |  |  |  |
| characteristics. 7.Generalized central limit theorem, domains of attraction, sub-exponential distributions. 8.Heavy-tail distribution detections, PP and QQ  | plots, Mean Exces  | s function,   |  |  |  |
| its empirical estimator, usage. 9. Return period of (insurance) events, record counting process, Gumbel method of exceedance. 10. Fluctuation of random  | n maxima, Fisher-T   | ïppett law,   |  |  |  |
| max-stability, maximum domain of attraction. 11.Generalized extreme value distribution, generalized Pareto distribution, properties and utilization. 12.E  | stimates of exceeda  | ance over   |  |  |  |
| threshold, POT methods, estimator of quantile, application. 13. Applications to real data from hydrology, geology, insurance, finance, numerou   | us other examples.   |   |  |  |  |
| 01MMD Mathematical Modelling of Traffic  | Z,ZK   | 5   |  |  |  |
| 1. Basic mathematical description of vehicular traffic - macroscopic and microscopic quantities, relations between them, fundamental diagram and phase   | e map. 2. Empirical  | knowledge   |  |  |  |
| about traffic flow - methodology of traffic data evaluation, 3s-unification procedure, two-phase theory, three-phase theory, VHM and link to capacity calcu  | ulations in physics of   | of traffic. 3.  |  |  |  |
| Traffic models - general overview, classification of models, examples, Greenbergs macroscopic model and its solution, Montrolls microscopic model and its  | s solution. 4. Lighthi   | ill-Whitham   |  |  |  |
| model - formulation and theoretical solution, Cole-Hopf transformation, formulation of associate Cauchy problem and its solution in distributions, Burgers equation. 5. Cellular traffic   |  |   |  |  |  |
| models - Nagel-Schreckenberg model, Fukui-Ischibaschi model, model TASEP and its theoretical solution by MPA. 6. Thermodynamic traffic models - va   | ariants, classificatio   | n by range  |  |  |  |
| and type of potential, Hamiltonian description, general solution methodology, solution of short-range model, connection between thermodynamic models   |  | -   |  |  |  |
| solution of middle-ranged model with logarithmic potential. 7. Vehicular Headway Modeling - an insight into the issue, empirical and theoretical knowledge   | <b>.</b> .   |   |  |  |  |
| admissibility of headway distributions, statistical rigidity and changes in its course, derivation of statistical rigidity for thermodynamic gas. 8. Statistical pro   | perties of traffic flow  | w - Poisson   |  |  |  |
| and semi-Poisson mode of transport, supra-random traffic states, their detection.  |  |   |  |  |  |
| 01MMNS Mathematical Modelling of Non-linear Systems  | ZK   | 3   |  |  |  |
| The course consists of basic terms and results of the theory of finite- and infinitedimensional dynamical systems generated by evolutionary differential   | equations, and des   | cription of   |  |  |  |
| bifurcations and chaos. Second part is devoted to the explanation of basic results of the fractal geometry dealing with attractors of such dyr   | namical systems.   |   |  |  |  |
| 01NAEX Design of Experiments   | Z,ZK   | 3   |  |  |  |
| 1. Introduction to the design of experiments and data analysis. 2. Completely randomized one-factor experiment: introduction of a fixed-effect model, test   | ts of equality of me   | an values,  |  |  |  |
| choice of number of observations. 3. Methods of multiple comparison: Bonferroni method, Scheffy method, Tukey method 4. Randomized complete blo  | ck design: model de  | efinition,  |  |  |  |
| equality effects tests, power of test, determining sample size. 5. Latin and Greco-Latin squares, balanced incomplete block design, model adequacy c   | hecking, residuals,  | multiple  |  |  |  |
| comparisons. 6. Two factor factorial design: statistical models and their properties for designs 2^2, 2^3 and 2^k, fractional factorial design, resolutions. 7.3^k   | factorial designs, c   | onfounding  |  |  |  |
| in 3 <sup>^</sup> k factorial design. 8. Models with random effects, factorials with mixed levels.   |  |   |  |  |  |
| 01NAH Theory of Random Processes   | ZK   | 3   |  |  |  |
| The course is devoted in part to the basic notions of the general theory of random processes and partially to the theory of stationary processes and seque   | nces both weakly a   | nd strongly   |  |  |  |
| stationary ones.   |  |   |  |  |  |
| 01NELO Nonlinear Optimization  | ZK   | 4   |  |  |  |
| Nonlinear optimization problems find their application in may areas of applied mathematics. The lecture covers the basics of mathematical programming th   |  | -   |  |  |  |
| optimization and basic methods for unconstrained and constrained optimization. The lecture is supplemented by illustrative exan  |  |   |  |  |  |
|  | nples.   |   |  |  |  |
|  | -  | 2   |  |  |  |
| 01NEUR1 Neural Networks and their Applications 1   | nples.<br>ZK   | 2   |  |  |  |
| 01NEUR1 Neural Networks and their Applications 1<br>Keywords: Neural networks, data separation, functional approximation, supervised learning  | ZK   |   |  |  |  |
| 01NEUR1         Neural Networks and their Applications 1<br>Keywords: Neural networks, data separation, functional approximation, supervised learning           01NEUR2         Theoretical Fundamentals of Neural Networks  | -  | 2<br>3  |  |  |  |
| 01NEUR1         Neural Networks and their Applications 1<br>Keywords: Neural networks, data separation, functional approximation, supervised learning           01NEUR2         Theoretical Fundamentals of Neural Networks<br>Keywords: Functional approximation, supervised learning, Vapnik-Chervonenkis-dimension  | ZK<br>ZK   | 3   |  |  |  |
| 01NEUR1         Neural Networks and their Applications 1<br>Keywords: Neural networks, data separation, functional approximation, supervised learning           01NEUR2         Theoretical Fundamentals of Neural Networks<br>Keywords: Functional approximation, supervised learning, Vapnik-Chervonenkis-dimension           01PRR         Advanced and Robust Regression Models  | ZK<br>ZK<br>ZK   | 3   |  |  |  |
| 01NEUR1         Neural Networks and their Applications 1<br>Keywords: Neural networks, data separation, functional approximation, supervised learning           01NEUR2         Theoretical Fundamentals of Neural Networks<br>Keywords: Functional approximation, supervised learning, Vapnik-Chervonenkis-dimension           01PRR         Advanced and Robust Regression Models           1.Introduction to robust regression - M-estimates, qualitative and quantitative robustness, influential functions, outliers, leverage points. 2.The least mediates   | ZK<br>ZK<br>ZK<br>dian of squares, the   | 3<br>2<br>e trimmed   |  |  |  |
| 01NEUR1         Neural Networks and their Applications 1<br>Keywords: Neural networks, data separation, functional approximation, supervised learning           01NEUR2         Theoretical Fundamentals of Neural Networks<br>Keywords: Functional approximation, supervised learning, Vapnik-Chervonenkis-dimension           01PRR         Advanced and Robust Regression Models           1.Introduction to robust regression - M-estimates, qualitative and quantitative robustness, influential functions, outliers, leverage points. 2.The least med<br>least squares and the least trimmed squares. 3.Weighted least squares and least weighted squares, algorithms, applications. 4.Instrumental weighted varies  | ZK<br>ZK<br>ZK<br>dian of squares, the<br>iables and their robu  | 3<br>2<br>e trimmed<br>ustification.  |  |  |  |
| 01NEUR1         Neural Networks and their Applications 1<br>Keywords: Neural networks, data separation, functional approximation, supervised learning           01NEUR2         Theoretical Fundamentals of Neural Networks<br>Keywords: Functional approximation, supervised learning, Vapnik-Chervonenkis-dimension           01PRR         Advanced and Robust Regression Models           1.Introduction to robust regression - M-estimates, qualitative and quantitative robustness, influential functions, outliers, leverage points. 2.The least med<br>least squares and the least trimmed squares. 3.Weighted least squares and least weighted squares, algorithms, applications. 4.Instrumental weighted varies<br>5.AR, MA, AR (I) MA, invertibility and stationarity condition. Smoothing of trend using curves, moving averages and exponential. Seasonal and cyclic com  | ZK<br>ZK<br>ZK<br>dian of squares, the<br>iables and their robu<br>ponents, tests of ra  | 3<br>2<br>e trimmed<br>ustification.<br>ndomness,   |  |  |  |
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| 01SMS1  | Student's seminar in mathematics 1  | Z                          | 2               |  |  |  |
|---|---|----------------------------|-----------------|--|--|--|
| 01SMS2  | Student's seminar in mathematics 2  | Z                          | 2               |  |  |  |
| 01SSI   | Social Systems and Their Simulations  | KZ                         | 4               |  |  |  |
| The course is dev   | oted to the issue of social systems modeling. That includes stochastic methods and methods of statistical physics for description and   | d analytical solution      | n of social     |  |  |  |
| interaction systems, implementation of particular models and comparison of the computer simulations results with the empirical data.  |   |                            |                 |  |  |  |
| 01SU2   | Machine Learning 2  | Z,ZK                       | 4               |  |  |  |
| -   | cs from the probability theory and machine learning (classical distributions, Bayes theorem, Kullback-Leibler divergence, curse of dimer  | -                          | - 1             |  |  |  |
|   | imum a posteriori estimators, Principle Component Analysis) 2.Decision trees: general schema, recursive partitioning, optimal partiti<br>boosting, random forests. 3.Examples of decision trees: Adaptive boosting AdaBoost, Gradient boosting, Xgboost. 4.Numerical meth       |                            |                 |  |  |  |
| 0 00 0  | e gradient, Newton and quasi-Newton, constrained extrema, Lagrangian). 5.Deep feedforward networks (hidden units, nonlinear activ   |                            | · ·             |  |  |  |
| loss functional, stoc   | hastic gradient descent, back-propagation algorithm) 6. Optimization for training deep models (regularization, algorithms with adaptive   | learning rates) 7.C        | onvolutional    |  |  |  |
| neural networks 8   | Recurrent neural networks 9. Advanced network architectures (autoencoders, Generative Adversarial networks) 10. Applications of o   | deep learning (clas        | sification,     |  |  |  |
|   | segmentation, image reconstruction)   |                            |                 |  |  |  |
| 01SUP   | Start-up Project  | KZ                         | 2               |  |  |  |
| 01SVK   | Student's Scientific Conference   |                            | 1               |  |  |  |
| 01TEH   | is the active participation of the student in one of the approved student conferences. The list of such conferences is defined by the co  | ZK                         | 2               |  |  |  |
|   | Game Theory<br>mes, normal games - impartial and partizan games. 2. Multidimensional tic-tac-toe, Hales Jewett theorem. 3. Game tree, Zermelo's   | 1                          |                 |  |  |  |
| -   | mal games, equivalence on games, MEX principle, Sprague-Grundy theorem. 5. Strategic games, pure and mixed strategies, domini-  |                            | -               |  |  |  |
|   | nin principle, von Neumann theorem. 7. Nash equilibrium, Nash theorem. 8. Cooperation of two players, Nash arbitration. 9. Coalition  | -                          |                 |  |  |  |
| 01TG  | Graph Theory  | ZK                         | 5               |  |  |  |
|   | graph theory. 2. Edge and vertex connectivity (Menger Theorem). 3. Bipartite graphs. 4. Trees and forests. 5. Spanning trees (Matrix-   |                            |                 |  |  |  |
| and Hamilton cycle  | es. 7. Maximal and perfect matching. 8. Edge coloring. 9. Flows in networks. 10. Vertex coloring. 11. Plannar graphs (Kuratowski theor  | em), vertex colorin        | g of planar     |  |  |  |
|   | graphs. 12. Spectrum of the adjacency matrix. 13. Extremal graph theory.  | 71/                        |                 |  |  |  |
| 01TIN   | Information Theory<br>explores the fundamental limits of the representation and transmission of information. We will focus on the definition and implication  | ZK<br>s of (information) e | 2               |  |  |  |
|   | orem, and the channel coding theorem. These concepts provide a vital background for researchers in the areas of data compression  | ,                          |                 |  |  |  |
| <b>j</b>  | and pattern recognition.  | ,                          | , ,             |  |  |  |
| 01TNM   | Random Matrix Theory  | ZK                         | 2               |  |  |  |
| Theory of random n  | natrices appeared first in 60's in the 20th century in connection with statistical physics and the theory of nucleis of atoms of heavy me   | tals. The main inter       | est of study    |  |  |  |
| is the distribution of  | eigenvalues of symmetric random matrices. In the 21st century the results of theory of random matrices were applied in theoretical co   | omputer science ar         | nd numerics     |  |  |  |
| 041104001   | for design of random algorithms.  | 1/7                        |                 |  |  |  |
| 01UMIN  | Probabilistic Models of Artificial Intelligence<br>oted to the survey of methods used for uncertainty processing in the field of artificial inteligence. The main attention is paid to so-call  | KZ                         | 2               |  |  |  |
|   | particularly to Bayesian networks.  | eu graphical Marko         | ov mouels,      |  |  |  |
| 01VUAM1   | Research Project 1  | Z                          | 6               |  |  |  |
|   | Research project on the selected topic under the supervision. Supervision and regular checking of the research project under pre  | paration.                  | -               |  |  |  |
| 01VUAM2   | Research Project 2  | KZ                         | 8               |  |  |  |
|   | Research project on the selected topic under the supervision. Supervision and regular checking of the research project under prepared on the selected topic under the supervision.  | paration.                  |                 |  |  |  |
| 01ZASIG   | Analysis and Processing of Diagnostic Signals   | ZK                         | 3               |  |  |  |
|   | Digital signal processing, signal transformations and filtrations, spectral and time-frequency analysis   |                            |                 |  |  |  |
| 01ZLMA  | Generalized Linear Models and Applications  | Z,ZK                       | 5               |  |  |  |
|   | ear models: exponential family, regularity conditions, score function. 2.Estimation of parameters: maximum likelihood estimates, nume<br>-Raphson, Fisher-scoring algorithm. 3.Testing of models: asymptotic distribution of the score function and the MLE estimates, models c |                            |                 |  |  |  |
|   | ential observations. 4.Analysis of covariance (ANCOVA), general model of analysis of covariance, one factor ANCOVA, multiple com  | •                          |                 |  |  |  |
|   | , normal model, Gumbel model, model parameters interpretation, odds ratio, tests, residuals. 6. Poisson regression: univariate and m  |                            |                 |  |  |  |
|   | model parameters interpretation, tests and residuals. 7. Probability models for contingency tables, log-linear models.  |                            |                 |  |  |  |
| 18AAD   | Applied Data Analysis   | Z                          | 3               |  |  |  |
| A practically focuse  | d subject that guides you through the topics of Big Data, neural networks, parallel computing, graph analysis, cloud technologies, de software or IoT solutions.  | ployment, and dev          | elopment of     |  |  |  |
| 18AMTL  | Matlab Applications   | KZ                         | 4               |  |  |  |
|   | tion of Matlab optimization toolbox for the solution of linear, quadratic, binary, integer an nonlinear programming tasks. Simulation of  |                            |                 |  |  |  |
| eyetematic applica  | generation. Analysis of trajectories, attractors and fractal sets including estimation of their properties.   |                            |                 |  |  |  |
| 18BI  | Business Intelligence   | KZ                         | 2               |  |  |  |
| The aim of the sub  | ject is to explain to the students different characteristics of production and analytical databases and a set of processes, know-how a  | nd tools (not only)        | to support      |  |  |  |
| decision-making act   | ivities within the organization. In addition to the basic concept of BI, listeners will get acquainted with the general methodology of impler   | nentation of custon        | n algorithms    |  |  |  |
| 40114   | derived from other theories and subjects into the BI environment.   | 71/                        | 4               |  |  |  |
| 18HA  | Heuristic Algorithms  | ZK<br>cally motivated bei  | 4<br>ristic are |  |  |  |
|   | ms of optimization operates on discrete or continuous domains. Brutal force, stochastic, greedy, physically, biologically and sociologi<br>included, used for optimum finding and compared.   | oany motivateu net         | anoue ale       |  |  |  |
| 18MEMC  | Monte Carlo Method  | Z,ZK                       | 4               |  |  |  |
|   | This course is devoted to the numerical method Monte Carlo and to its selected applications.  | _,、                        |                 |  |  |  |
| 18SQL   | SQL Applications  | Z                          | 2               |  |  |  |
|   | Practical realization of database system according to general principles of database analysis.  | ·                          |                 |  |  |  |
| 18TFT   | Financial Markets Theory  | KZ                         | 4               |  |  |  |
|   | ument prices are unknown in advance to financial market participants, financial derivatives are currently being used as common instrum  |                            | -               |  |  |  |
| from price instability of financial assets. The theory of financial markets uses the knowledge of mathematical analysis and statistics to manage the portfolio of risk assets and the valuation of sophisticated financial instruments in the form of derivatives such as swaps, forwards, futures and options. |   |                            |                 |  |  |  |
| valuation of sophisticated infancial instruments in the form of derivatives such as swaps, forwards, futures and options.   |   |                            |                 |  |  |  |

18ZDFT

#### Financial Markets Data Processing

The course enables students to combine knowledge of numerical methods, Matlab programming and financial mathematics to solve practical problems in finance such as portfolio optimization, risk management and valuation of financial derivatives, especially options of different types. Upon completion of the course the student will be able to formulate and numerically solve concrete problems in the given field and subsequently implement their solutions in practice.

ΚZ

4

For updated information see <u>http://bilakniha.cvut.cz/en/FF.html</u> Generated: day 2025-06-06, time 04:18.