## Study plan

# Name of study plan: Quantum Informatics

Faculty/Institute/Others:

Department:

Branch of study guaranteed by the department: Welcome page

Garantor of the study branch: Program of study: Welcome page Type of study: unknown full-time

Required credits: 116
Elective courses credits: 4
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: 96

The role of the block: PP

Code of the group: QNI-PP

Name of the group: Quantum Informatics

Requirement credits in the group: In this group you have to gain 96 credits

Requirement courses in the group: In this group you have to complete 12 courses

Credits in the group: 96 Note on the group:

QNI-KKP

Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
QNI-KKP	Cryptology and Quantum Computing Róbert Lórencz	Z,ZK	6	2P+2C	Z	PP
QNI-KOS	<b>Quantum Optical Communications and Networks</b>	Z,ZK	6	2P+2C	L	PP
QNI-QC1	Quantum Computation 1  Marcel Ji ina	Z,ZK	6	2P+2C	Z	PP
QNI-QC2	Quantum Computing 2 Aurél Gábor Gábris Aurél Gábor Gábris (Gar.)	Z,ZK	6	2P+2C	L	PP
QNI-LOM	Linear Optimization and Methods  Dušan Knop	Z,ZK	5	2P+1C	Z	PP
QNI-DIP	Diploma Project  Zden k Muziká Zden k Muziká (Gar.)	Z	30	270ZP	L,Z	PP
QNI-MPR	Master Project Zden k Muziká Zden k Muziká Zden k Muziká (Gar.)	Z	7		Z,L	PP
QNI-MQI	Mathematics for Quantum Informatics Št pán Starosta	Z,ZK	6	2P+2C	Z	PP
QNI-PPS	Programming of parallel systems Pavel Tvrdík Pavel Tvrdík Pavel Tvrdík (Gar.)	Z,ZK	6	2P+2C	L	PP
QNI-TIN	Information Theory Pavel Hrabák Pavel Hrabák (Gar.)	Z,ZK	6	2P+2C	L	PP
QNI-CPX	Complexity Theory Dušan Knop	Z,ZK	6	3P+1C	Z	PP
QNI-UKT	Introduction to Quantum Theory	Z,ZK	6	2P+2C	Z	PP

## Characteristics of the courses of this group of Study Plan: Code=QNI-PP Name=Quantum Informatics

Cryptology and Quantum Computing

The course covers methods and algorithms of cryptology and their relation to quantum computing. In the first introductory lectures, students will be introduced to the basic principles
and algorithms of cryptography. Following these topics, students will be introduced to basic cryptanalytic methods. Then some cryptanalytic algorithms running on quantum computers
will be presented. In this context, the problem of security of related cryptographic schemes will be discussed. The next lectures will be devoted to post-quantum algorithms. The last
lectures deal with cryptosystems using quantum phenomena.

Z,ZK

QNI-KOS Quantum Optical Communications and Networks The course focuses on the basic principles and technologies for building and using quantum networks. Students will learn about the key components of quantum networks, including quantum repeaters, routers and switches, and their role in creating a scalable quantum Internet. Emphasis will be placed on quantum cryptography systems. Students will also learn the fundamentals of optics, optical networks, and classical cryptography as they relate to quantum key distribution (QKD) and quantum networks. The course will cover types and architectures of QKD systems (including practical implementation of quantum protocols) according to international standards, key generation and distribution in these systems, and integration of QKD with classical communication systems. Students will also have the opportunity to explore satellite and FSO QKD systems and integrated quantum photonics and electronics. QNI-QC1 Quantum Computation 1 Z,ZK The course introduces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantum computation uses quantum circuits, which will be demonstrated in the Qiskit SDK. The course will gradually introduce the student to such concepts the state of a quantum system and its visualization, measurements, basic gates and their composition, and the so-called entanglement. The student will be introduced to the BB84 and E91 protocols as demonstrations of the properties of quantum states. The course will also cover quantum teleportation, quantum oracle queries, the Deutsch-Jozsa algorithm, the quantum Fourier transform, the phase estimation algorithm, and the Shor algorithm. QNI-QC2 Quantum Computing 2 Z,ZK Quantum Computing 2 focuses on advanced quantum algorithms and their implementations: the Grover algorithm and its applications, quantum algorithms solving linear algebra problems, HHL for solving systems of linear equations. In the course we also introduce students to variational methods and error correction. QNI-LOM Linear Optimization and Methods Z.ZK Students learn the applications of optimization methods in computer science, economics, and industry. They are aware of practical importance of linear and integer programming. They are able to work with optimization software and are familiar with languages used in programming of that software. They get skills in formalization of optimization problems in computer science (such as scheduling of tasks to processors, analysis of network flows), distribution and allocation of resources (transportation problems, travelling salesman problems, etc.), issues from economics, and modelling of conflicts via the game theory. They get an overview of computational complexity of optimization problems. They get orientation in algorithms in linear programming QNI-DIP Diploma Project Independent work of the student under the guidance of the thesis supervisor. Teaching is based on individual consultations with the thesis supervisor or other consultants. The scope of teaching 30 ECTS (i.e. about 900 hours) includes consultations, preparation of theoretical and practical parts of the thesis, writing, preparation for defence and defence of the thesis before the commission. The course supervisor guarantees the quality of the Masters thesis assignment and its compliance with the graduate profile. Master Project 1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. The external supervisor enters the information on granting the credit using the form "Granting credit from the external supervisor of the final thesis" (http://fit.cvut.cz/student/studijni/formulare). The completed and signed form must be delivered in person or by email to the SZZ coordinator, who will arrange for the credit to be granted. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester. QNI-MQI Mathematics for Quantum Informatics Z,ZK 6 Linear algebra on finite dimensional spaces with scalar product, Hilbert spaces, Dirac's bra-ket formalism, normal, Hermitian and unitary operators, operator spectrum, orthonormalization diagonalization, matrix exponential, tensor product of vector spaces and operators. Discrete Fourier transform and fast Fourier transform. Programming of parallel systems Z,ZK Nowadays, multi-core processors and GPU accelerators have become common components of computing clusters and high-performance computing systems, so knowledge and skills related to parallel programming are essential for every computer scientist. The aim of this course is to introduce students to the architectures and programming methods of parallel computers with shared memory, GPU accelerators, or with distributed memory. To effectively use these modern computing systems, it is essential to combine parallelization techniques at all three levels. Students will gain knowledge of the relevant programming models, languages and environments. They will become familiar with fundamental parallel algorithms and be able to analyze the limitations, efficiency, and scalability of parallel solutions to selected problems on high-performance computing systems. In addition to the necessary theory in lectures, students will gain practical experience and skills in programming in OpenMP, CUDA and MPI environments. QNI-TIN Information Theory The course focuses on the mathematical description of a random message source, its coding and transmission of the source through a noisy channel. The coding problem is addressed probabilistically, the relation of the mean length of the optimal code with the entropy and entropy rate of the random source is emphasized. In the case of the noisy channel we focus on the set of typical sequences and its appropriate coding by self-correcting codes. The course includes a reminder of necessary concepts such as conditional distributions, goodness-of-fit and independence tests, and an introduction to random chains. QNI-CPX Complexity Theory 7.7K 6 Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems. Introduction to Quantum Theory Z,ZK QNI-UKT interpretation of quantum theory are explained using simple models mainly from finite-dimensional quantum mechanics. Emphasis is placed on further applications of quantum theory

to information processing and communication. Possible physical realizations of a qubit, description of multipartite systems, quantum entanglement and its applications are discussed. The course concludes with a description of continuous quantum systems in infinite-dimensional Hilbert spaces, in particular the linear harmonic oscillator as a description of the mode of a quantized electromagnetic field.

Name of the block: Compulsory elective courses

Minimal number of credits of the block: 20

The role of the block: PV

Code of the group: QNI-PV

Name of the group: Compulsory elective courses of the QNI Quantum Informatics program

Requirement credits in the group: In this group you have to gain at least 20 credits (at most 63)

Requirement courses in the group: In this group you have to complete at least 4 courses (at most 12)

Credits in the group: 20

Note on the group:

Beware of the knowledge prerequisite of the QNI-QML course. You can enroll only with the previous knowledge, which is discussed in the following bachelor's courses: BI-ML1.21 Strojové učení 1 BI-ML2.21 Strojové učení 2

Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
QNI-AVM	Adiabatic computing and variational methods	Z,ZK	6	2P+2C	*	PV
QNI-QEC	Quantum error correction	Z,ZK	5	2P+2C	Z	PV
QNI-QOM	Quantum Optics, Metrology, Sensing and Imaging	Z,ZK	5	2P+2C	Z	PV
QNI-QML	Quantum machine learning Daniel Vašata	Z,ZK	5	2P+1C	Z	PV
QNI-NMK	Numerical methods for quantum computation	Z,ZK	5	2P+2C	Z	PV
QNI-OQC	Optical quantum computing  Aurél Gábor Gábris	Z,ZK	5	2P+1C		PV
QNI-OPM	Optical measurements	Z,ZK	6	2P+2C		PV
QNI-OVV	Optimization for Scientific Computing	Z,ZK	5	2P+1C		PV
QNI-PNM	Parallelization of numerical methods	Z,ZK	5	2P+2C		PV
QNI-PJK	Programming languages for quantum computing	Z,ZK	5	2P+1C	L	PV
QNI-VOT	Fiber Optic Technology	Z,ZK	6	2P+2C		PV
QNI-PON	Selected Topics in Optimization and Numerical mathematics Karel Klouda Karel Klouda Karel Klouda (Gar.)	Z,ZK	5	2P+1C	L	PV

### Characteristics of the courses of this group of Study Plan: Code=QNI-PV Name=Compulsory elective courses of the QNI Quantum Informatics program

QNI-AVM Adiabatic computing and variational methods The course introduces adiabatic computing and variational quantum algorithms (VQA). We start with a broad introduction to variational methods in physical chemistry (e.g., for calculating ground state of small molecules) and a recapitulation of advances in theoretical computer science (computational complexity and problems such as MAXCUT). We will present the EQA Conjecture and the unique games conjecture. We will present the adiabatic theorem and quantum speedup by quantum annealing (QA). We will build up an understanding of variational quantum algorithms by introducing and analysing, in turn, Variational quantum eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), and their Warm-started variants. As applications, we will highlight variational solvers for systems of linear equations and variational solvers for Markowitz portfolio management, with some discussion of the challenges in benchmarking of VQA.

#### QNI-QEC Quantum error correction

In this course, we will build a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapters from the classical theory will be summarized,

atop of which we then present the quantum analogy. We will show how coherently stored quantum information can be made robust to loss and noise. We conclude the course by arriving at the principle of fault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime and thus achieve correct results even with erroneous bits, gates or measurements.

#### QNI-QOM Quantum Optics, Metrology, Sensing and Imaging

Z,ZK

Students are given an introduction to the quantum theory of light and related fundamental principles with an emphasis on practical aspects. They acquire the theoretical and experimental foundations for the development of specifically quantum mechanical approaches to metrology and imaging in quantum computing and communications. Specific problems discussed include elementary processes with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phenomena with photons, methods of suppressing optical aberrations and dispersion. The various techniques are explained theoretically and also using experiments that demonstrate these principles in practice.

### QNI-QML Quantum machine learning

The aim of the course is to introduce students to quantum machine learning. Students will first learn theoretically and practically about the quantum representation of classical data. Next, they will explore kernel methods, the quantum SVM model, and the use of quantum variational methods in supervised learning scenarios. The course will also introduce quantum neural networks and quantum generative adversarial models in unsupervised learning scenarios. The primary focus of the course is quantum algorithms for classical data. The exercises will use the pandas and qiskit libraries for Python to work with data and models.

## Numerical methods for quantum computation

The course is devoted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equations. It explains finite-difference, finite-element and finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advances in methods solving the mentioned problems.

### QNI-OQC Optical quantum computing

Z,ZK

The course covers the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications using quantum programming libraries, Strawberry Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and quantum supremacy. Applications feasible on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vibration simulations.

### QNI-OPM Optical measurements

The aim of this course is to acquaint students with optical measurement methods from the detection of microparticles, non-regulation and surface breaches, through the use of fiber optics in areas where it is not possible to use standard electronic sensors, or in places with increased risk of explosion and in hospitals, lidars used in intelligent transport infrastructures, to macroscopic sensing (remote sensing) of the Earth, atmosphere and space. The inclusion of these measurement methods requires in particular an understanding of the physical mechanisms on which they are based, as well as knowledge of measurement procedures and specifics in data processing and reconstruction.

### Optimization for Scientific Computing

The content of the course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimal control, applications for QC, genetic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving these problems.

### QNI-PNM Parallelization of numerical methods

5

The content of the course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of these methods in QC. Students are also introduced to modern trends in the field of solving these problems.

### QNI-PJK Programming languages for quantum computing

5

Computational models for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quantum computation: imperative languages (Silq), functional languages (QML, Quipper). ). In the seminars the student will learn the basics of programming in the higher programming language Silq.

QNI-VOT Fiber Optic Technology

Z.ZK

6

The aim of the course is to introduce the mechanisms of optical wave propagation in optical fibres and fibre components. Furthermore, the knowledge of optical measurement techniques and measurement methods for the characterisation of optical fibres. The content includes both methodologies for measuring design and transmission parameters for optical communication systems such as numerical aperture, attenuation, dispersion, as well as measurements of basic characteristics of active and passive elements of optical communication systems - connectors, couplers, coupling elements, refractive indices.

QNI-PON Selected Topics in Optimization and Numerical mathematics

Z,ZK

5

Students will be introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the basic knowledge of continuous optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially from numerical linear algebra.

Name of the block: Elective courses Minimal number of credits of the block: 0

The role of the block: V

Code of the group: QNI-V

Name of the group: Purely Elective Master's Courses in the programu Quantum Informatics

Requirement credits in the group: Requirement courses in the group:

Credits in the group: 0

Note on the group:

In addition to the courses listed here, you can enroll as an elective any course that is offered within your study program and form of study that you did not enroll as a compulsory subject in the program/branch/specialization or a compulsory elective course. Courses of this group that a student has completed in the bachelor study at CTU cannot be re-completed.

	has completed in the bachelor study at CTU cannot be	e re-comple	ted.			
Code	Name of the course / Name of the group of courses (in case of groups of courses the list of codes of their members) Tutors, authors and guarantors (gar.)	Completion	Credits	Scope	Semester	Role
NI-AOA	Completing a professional event Zden k Muziká	Z	1			V
NI-ATH	AlgorithmicTheories of Games Tomáš Valla, Dušan Knop <b>Tomáš Valla</b> Tomáš Valla (Gar.)	Z,ZK	4	2P+2C	L	V
NI-AFP	Applied Functional Programming Robert Pergl, Marek Suchánek, Daniel N mec Robert Pergl Robert Pergl (Gar.)	KZ	5	2P+1C	L	V
NI-VGA	Video Games Architecture  Jan Matoušek	Z,ZK	5	2P+1C	Z	V
NI-APH	Architecture of computer games  Adam Vesecký Adam Vesecký (Gar.)	Z,ZK	4	2P+1C	Z	V
NI-BPS	Wireless Computer Networks Alexandru Moucha, Ji í Kašpar Alexandru Moucha Alexandru Moucha (Gar.)	Z,ZK	4	2P+1C	L	V
NIE-BLO	Blockchain Josef Gattermayer, Marek Bielik, Jakub R ži ka, Róbert Lórencz Josef Gattermayer Róbert Lórencz (Gar.)	Z,ZK	5	1P+2C	Z	V
NI-CTF	Capture The Flag Ji í Dostál, Martin Šutovský, Ivana Trummová, Ladislav Marko, František Ková <b>Ji í Dostál</b> Ji í Dostál (Gar.)	KZ	4	3C	Z	V
NI-DPH	Game Design Adam Vesecký	Z,ZK	5	2P+1C	L	V
NI-DSW	Design Sprint Michal Manda, Ond ej Brém Michal Manda David Pešek (Gar.)	Z	2	30B	Z	V
NI-PSD	Public Services Design Ond ej Brém, David Pešek David Pešek Ond ej Brém (Gar.)	KZ	4	1P+2C		V
NI-DID	Digital drawing Denisa Nová ková, Eliška Novotná Denisa Nová ková Denisa Nová ková (Gar.)	Z	2	4C	Z,L	V
NI-DZO	Digital Image Processing	Z,ZK	4	2P+1C	L	V
NI-DDM	Distributed Data Mining	KZ	4	3C	L	V
NI-PAM	Efficient Preprocessing and Parameterized Algorithms Ond ej Suchý Ond ej Suchý (Gar.)	Z,ZK	4	2P+1C	L	V
NI-ESC	Experimental Project Course Ond ej Brém, Jan Matoušek Ond ej Brém Ond ej Brém (Gar.)	KZ	8	0P+30R+52C	L	V
NI-GLR	Games and reinforcement learning	Z,ZK	4	2P+2C	L	V
NI-GNN	Graph Neural Networks Miroslav epek Miroslav epek (Gar.)	Z,ZK	4	1P+1C	L	V
NI-GRI	Grid Computing André Sopczak, Petr Fiedler Pavel Tvrdík André Sopczak (Gar.)	Z,ZK	5	2P+1C	Z	V
NI-HCM	Mind Hacking Marcel Ji ina, Josef Holý Marcel Ji ina Marcel Ji ina (Gar.)	ZK	5	2P+1C	Z	V
NI-HSC	Side-Channel Analysis in Hardware Vojt ch Miškovský, Petr Socha Petr Socha Vojt ch Miškovský (Gar.)	Z,ZK	4	2P+2C	Z	V

NI-HMI2	History of Mathematics and Informatics  Alena Šolcová Alena Šolcová (Gar.)	ZK	3	2P+1C	Z	V
NI-IBE	Information Security	ZK	2	2P	Z	V
NI-IVS	Intelligent embedded systems Miroslav Skrbek Miroslav Skrbek (Gar.)	KZ	4	1P+3C	L	V
NI-IKM	Internet and Classification Methods  Martin Hole a Martin Hole a Martin Hole a (Gar.)	Z,ZK	4	1P+1C	L	V
NI-IAM	Internet and Multimedia	Z,ZK	4	2P+1C	L	V
NI-IOT	Internet of Things	Z,ZK	4	2P+1C	L	V
FITE-EHD	Introduction to European Economic History Tomáš Evan	Z,ZK	3	2P+1C	L	V
NI-KTH	Combinatorial Theories of Games Tomáš Valla Tomáš Valla (Gar.)	Z,ZK	4	2P+1C	L	V
NI-FMT	Finite model theory	Z,ZK	4	2P+1C	L	V
NI-CCC	Tomáš Jakl Tomáš Jakl Tomáš Jakl (Gar.)  Creative Coding and Computational Art	KZ	4	1P+2C	Z,L	V
NI-KYB	Josef Kortán, Radek Richtr Radek Richtr Radek Richtr (Gar.)  Cybernality	ZK	5	2P	Z	V
NI-LSM2	Statistical Modelling Lab	KZ	5	3C	Z,L	V
	Kamil Dedecius Kamil Dedecius Kamil Dedecius (Gar.)		3			V
NI-LOM	Linear Optimization and Methods Dušan Knop Dušan Knop (Gar.)	Z,ZK	5	2P+1C	Z	V
NI-MPL	Managerial Psychology Jan Fiala Jan Fiala (Gar.)	ZK	2	2P	Z,L	V
NI-MSI	Mathematical Structures in Computer Science  Jan Starý	Z,ZK	4	2P+1C	L	V
NI-MZI	Mathematics for data science Št pán Starosta	Z,ZK	4	2P+1C	L	V
FIT-ITI	Modern IT infrastructure	Z,ZK	5	2P+1C	Z,L	V
NI-MOP	Modern Object-Oriented Programming in Pharo  Jan Blizni enko Robert Pergl Robert Pergl (Gar.)	KZ	4	3C	Z	V
NI-NLM	Neural Language Models	Z	5	2P+1C	L	V
NI-NMU	New media in art and design Zden k Svejkovský Zden k Svejkovský (Gar.)	ZK	3	2P+0C	Z	V
NI-OLI	Linux Drivers Miroslav Skrbek, Jaroslav Borecký Maroslav Skrbek (Gar.)	Z,ZK	4	2P+2C	L	V
NIE-PML	Personalized Machine Learning Rodrigo Augusto Da Silva Alves Karel Klouda Rodrigo Augusto Da Silva Alves (Gar.)	Z,ZK	5	2P+1C	Z	V
NI-ARI	Computer arithmetic Pavel Kubalík Pavel Kubalík Alois Pluhá ek (Gar.)	Z,ZK	4	2P+1C	Z,L	V
NI-PG1	Computer Grafics 1 Radek Richtr Radek Richtr (Gar.)	ZK	4	2P+1C	L	V
NI-EDW	Enterprise Data Warehouse Systems  Jakub Krej í, Robert Kotlá Jakub Krej í Magda Friedjungová (Gar.)	Z,ZK	5	1P+1C	L	V
NI-PVR	Advanced Virtual Reality Petr Pauš Petr Pauš Petr Pauš (Gar.)	KZ	4	2P+1C	Z	V
NI-AML	Advanced machine learning Miroslav epek, Rodrigo Augusto Da Silva Alves, Petr Šimánek, Vojt ch Rybá, Zden k Buk Miroslav epek Miroslav epek (Gar.)	Z,ZK	5	2P + 1C	L	V
NI-IOS	Advanced techniques in iOS applications Rostislav Babá ek, Jakub Olejník, Igor Rosocha Martin P Ipitel Martin P Ipitel (Gar.)	KZ	4	2P+2C	L	V
NI-APT	Advanced Program Testing  Pierre Donat-Bouillud Pierre Donat-Bouillud (Gar.)	Z,ZK	5	2P+1C	Z	V
NI-PVS	Advanced embedded systems Miroslav Skrbek	Z,ZK	4	2P+2C	Z	V
NI-DNP	Advanced .NET  Nikolas Jíša, David Šenký David Šenký Nikolas Jíša (Gar.)	Z,ZK	4	2P+1C	Z	V
NI-PYT	Advanced Python	KZ	4	3C	Z	V
NIE-PDL	Practical Deep Learning Martin Barus, Yauhen Babakhin Karel Klouda Karel Klouda (Gar.)	KZ	5	2P+1C	Z	V
NI-GOL	Programming of distributed systems in GO	KZ	5	0P+3C	Z	V
NI-PSL	Programming in Scala Ji í Dan ek Ji í Dan ek Ji í Dan ek (Gar.)	Z,ZK	4	2P+1C	Z	V
NI-RUB	Programming in Ruby Cyril erný Cyril erný Cyril erný (Gar.)	KZ	4	3C	Z	V
NI-ROZ	Pattern Recognition Radek Richtr, Michal Haindl Michal Haindl (Gar.)	Z,ZK	5	2P+1C	Z	V
NI-PLS1	Programming Language Seminar Pierre Donat-Bouillud	Z	2	0P+1C	Z	V
NI-PLS2	Programming Language Seminar	Z	2	0P+1C	L	V

	Tierre Bonat-Bouniau					
NI-PLS4	Programming Language Seminar Pierre Donat-Bouillud, Filip K ikava Pierre Donat-Bouillud Pierre Donat-Bouillud (Gar.)	Z	2	0P+1C	L	V
NI-SCE1	Computer Engineering Seminar Master I Hana Kubátová Miroslav Skrbek Hana Kubátová (Gar.)	Z	4	2C	L,Z	V
NI-SCE2	Computer Engineering Seminar Master II Hana Kubátová Hana Kubátová Hana Kubátová (Gar.)	Z	4	2C	L,Z	V
NI-SZ1	Knowledge Engineering Seminar Master I Pavel Kordík Magda Friedjungová (Gar.)	Z	4	2C	L,Z	V
NI-SZ2	Knowledge Engineering Seminar Master II Pavel Kordík Magda Friedjungová (Gar.)	Z	4	2C	L,Z	V
PI-SCN	Seminars on Digital Design Petr Fišer Petr Fišer (Gar.)	ZK	4	2P+1C	Z,L	V
NI-MLP	Machine Learning in Practice Jan Hu in Daniel Vašata Daniel Vašata (Gar.)	Z,ZK	5	2P+1C	Z	V
BI-ML1.21	Machine Learning 1 Karel Klouda, Daniel Vašata Daniel Vašata (Gar.)	Z,ZK	5	2P+2C	Z	V
BI-ML2.21	Machine Learning 2 Daniel Vašata Daniel Vašata (Gar.)	Z,ZK	5	2P+2C	L	V
FIT-SEP	World Economy and Business Tomás Evan	Z,ZK	4	2P+2C	L	V
NI-SEP	World Economy and Business Tomáš Evan Tomáš Evan Tomáš Evan (Gar.)	Z,ZK	4	2P+1C	Z,L	V
NI-TVR	Virtual Reality Technology Tomáš Nová ek Tomáš Nová ek (Gar.)	Z,ZK	3	1P+1C	L,Z	V
NI-TS1	Theoretical Seminar Master I Tomáš Valla, Dušan Knop, Ond ej Suchý Tomáš Valla Tomáš Valla (Gar.)	Z	4	2C	Z	V
NI-TS2	Theoretical Seminar Master II Tomáš Valla, Ond ej Suchý Tomáš Valla Tomáš Valla (Gar.)	Z	4	2C	L	V
NI-TS3	Theoretical Seminar Master III Tomáš Valla, Ond ej Suchý Tomáš Valla Tomáš Valla (Gar.)	Z	4	2C	Z	V
NI-TS4	Theoretical Seminar Master IV Tomáš Valla, Ond ej Suchý Tomáš Valla Ond ej Suchý (Gar.)	Z	4	2C	L	V
NI-TKA	Category Theory Jan Starý Jan Starý (Gar.)	Z,ZK	4	2P+1C	L	V
NI-TNN	Theory of Neural Networks Martin Hole a Martin Hole a Martin Hole a (Gar.)	Z,ZK	5	2P+1C	L	V
NI-CPX	Complexity Theory  Dušan Knop, Ond ej Suchý Ond ej Suchý (Gar.)	Z,ZK	5	3P+1C	Z	V
FI-TOP	Academic writing Tomáš Nová ek	Z	2	10B	Z	V
NI-DVG	Introduction to Discrete and Computational Geometry Maria Saumell Mendiola Maria Saumell Mendiola (Gar.)	Z,ZK	5	2P+1C	L	V
NI-VOL	Elections Dušan Knop Dušan Knop (Gar.)	Z,ZK	5	2P+1C	L	V
NI-VYC	Computability Jan Starý Jan Starý (Gar.)	Z,ZK	4	2P+2C	L	V
NI-VPR	Research Project Št pán Starosta Št pán Starosta Št pán Starosta (Gar.)	Z	5		Z,L	V
NI-ZS10	Master internship abroad for 10 credits  Zden k Muziká Zden k Muziká (Gar.)	Z	10		Z,L	V
NI-ZS20	Master internship abroad for 20 credits  Zden k Muziká Zden k Muziká (Gar.)	Z	20		Z,L	V
NI-ZS30	Master internship abroad for 30 credits  Zden k Muziká Zden k Muziká (Gar.)	Z	30		Z,L	V
Characteristics of the Quantum Informatics	courses of this group of Study Plan: Code=QNI-V Name=Pure	ly Elective M	laster's (	Courses i	n the pro	gramu
NI-AOA Co	mpleting a professional event				Z	1
	n a one-off professional event, usually a lecture by a foreign guest of the FIT CTU, con- e by the vice-dean for pedagogical activities or the vice-dean for science and research		-	_	-	
	orithmicTheories of Games	and is presented	a widini uie		Z,ZK	4
, ,	porturnite friedries of Games branch of mathematics, which has broad applications in economy, biology, politics and	computer science	e. This the			•
-	itive process by designinng a mathematical model and investigating the strategies. The	•		-		-
	ome where no player wants to deviate from his strategy. Due to the recent development					-

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Programming Language Seminar Pierre Donat-Bouillud

NI-PLS3

NI-AFP

which are the states of the game where no player wants to deviate from his strategy. Due to the recent development of computers, internet, social networks, online auctions, advertising, multiagent systems and other concepts the algorithmic point of view is gaining attention. In addition to existential questions we study the problems of efficient computation of various

This course is presented in Czech. Functional programming represents one of the traditional programming paradigms. Traditional and novel functional programming languages are on the rise nowadays and the functional paradigm becomes an important construct of traditionally imperative languages (C++, C#, Java). As such, mastering this paradigm becomes a

solution concepts. In this course we introduce the basics of game theory of many players, solution concept (usually equilibria) and methods of their computation.

Applied Functional Programming

necessary competence of a software engineer: the theory and especially the practice.

NI-VGA	Video Games Architecture	Z,ZK	5
	de range of topics, procedures and methodologies related to the development of computer games - from a technical point of v ew. In the lectures, students will be guided through the history of development, the structure of game engines, component an		
	sics, graphics, artificial intelligence and multiplayer. The exercises will then cover selected technological topics in greater deta		
some game mechanics,	in the form of practical demonstrations.		
NI-APH	Architecture of computer games	Z,ZK	4
=	c understanding of the various issues in the field of computer games development, especially from a technical point of view, but a et a grasp of component-oriented and functional-oriented architecture, game mechanics, decision-making processes and base	_	
	ey will also understand the basics of pathfinding, networking and scripting and apply them in practical exercises (labs). An imp	="	- 1
•	ple game, with a strong focus on nontrivial game mechanics.		
NI-BPS	Wireless Computer Networks	Z,ZK	4
	It the modern technologies, protocols, and standards for wireless networks. They will understand the routing mechanisms in a and data flow control mechanisms. They will also learn about principles of communication in sensor networks. They get known		
	and data now confront medianisms. They will also learn about principles of communication in sensor networks. They get known diget skills of configuration of wireless network elements and simulation of wireless networks using suitable tools.	vieuge or security	Thechanisms
NIE-BLO	Blockchain	Z,ZK	5
	d the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain plat	=	- 1
	re decentralized application, and assess whether integration of a blockchain is suitable for a given problem.The course place ockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares t		-
•	tion of blockchain-based solutions in both academia and business.	ne students for in	ipiementing of
NI-CTF	Capture The Flag	KZ	4
	to introduce students to CTF competitions and let them gain practical experience in the field of cyber security.	<u> </u>	
NI-DPH	Game Design	Z,ZK	5
· · · · · · · · · · · · · · · · · · ·	ts the NI-APH (Architecture of Computer Games) and BI-VHS (Virtual gaming worlds) course, while focusing primarily on gam owledge of the principles used for games design, such as: level design, gameplay design, character design, game mechanics	-	
· · · · · · · · · · · · · · · · · · ·	students will get an overview of game development from the designer's perspective, from theoretical concepts to practical imp		
projects.			
NI-DSW	Design Sprint	Z	2
· ·	ojects using the Design Sprint method, developed by Google. THanks to this method the teams are able to go from idea to val will get familiar with the method as participants. Through practical challenges they will try the whole 5 day process starting w		
testing the prototypes (p		illi researcii and i	misimig with
NI-PSD	Public Services Design	KZ	4
	e students to specifics of UX, Service design and development for public sector. We will look into the design and development	•	
	ignesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration ents-designers as well as clients.	on with client repr	esentatives.
NI-DID	Digital drawing	Z	2
	e students to the basic principals of digital drawing and graphical design. Students will gain understanding of composition, pe		1
	y in their own design works. Students will also gain experience in drawing and painting with digital and analog tools. The cour	•	e who wants to
	g and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practice gai Digital Image Processing		4
NI-DZO This course presents a	Digital image Processing comprehensive overview of modern methods for interactive editing of digital images and video. It mainly deals with practical a	Z,ZK   algorithms that are	
·	interesting theoretical basis. Visually attractive applications provide better understanding of basic theoretical background that is	-	
	ing. This course will introduce algorithms solving the following practical applications: edge-aware editing, tone mapping, HDR	•	-
	raction, hybrid images, gradient domain editing, seamless image stitching and cloning, digital photo-montage, color-to-gray c ossible image deformation, free-form image registration, texture synthesis, interactive segmentation, colorization, painting, ac		
NI-DDM	Distributed Data Mining	KZ	4
	e-of-the-art approaches for distributed data mining and parallelization of machine learning algorithms. Students will gain hand		
	ork Apache Spark and with existing distributed DM / ML algorithms. They will learn principles of their parallel implementation	s and will be capa	able to propose
	e other algorithms. The course is prezented in czech language.	7 71/	4
NI-PAM There are many optimiz	Efficient Preprocessing and Parameterized Algorithms  ation problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often neces	Z,ZK	4 se problems
	vill demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often or		
. , ,	s from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity expo	• ,	
	input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomia the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent soluti		
·='	ed algorithm design methods and we will also show how to prove that for some problem (and parameter) such an algorithm (		•
will also not miss out the	e relations to other approaches to hard problems such as moderately exponential algorithms or approximation schemes.		
NI-ESC	Experimental Project Course	KZ	8
	arse offers a holistic exploration of the design process, providing students with a well-rounded understanding of the principles -driven solutions that are user-centric and industry-relevant. Throughout the semester, students will work on real-world design		
	egrate theory with practical application. Through a hands-on, project-based learning approach, students will develop their ski		- 1
user experience evaluat	ion, as well as gain experience working in a team to design and prototype a functional solution."		_
NI-GLR	Games and reinforcement learning	Z,ZK	4
	nt learning is very hot recently, because of advances in deep learning, recurrent neural networks and general artificial intellig I and practical background so you can participate in related research activities. Presented in English.	ence. This course	is intended to
NI-GNN	Graph Neural Networks	Z,ZK	4
	students to advanced artificial intelligence techniques for working with graphs. Lectures will focus on the latest graph neural n		
•	s, edges and entire graphs. The techniques discussed cover various types of graphs, including time-varying graphs. The last	part of the course	also covers
	terpretability of graph neural networks. In the exercises, students will try out selected techniques and problems.	7 71/	
NI-GRI Grid computing and gain	Grid Computing  n knowledge about the world-wide network and computing infrastructure.	Z,ZK	5
. 3 3	• •		

NI-HCM Mind Hacking Cognitive security is an emerging discipline that is closely related to cyber security. While the domain of cyber security is the protection of networks, information systems and assets, the domain of cognitive security is the protection of the human mind from intentional and unintentional digital manipulation. The topic of cognitive security is growing in importance in the context of information warfare, increasing digital dependence and the development of artificial intelligence, where these phenomena from the Internet environment have real societal impacts such as disruption of social cohesion, threats to democracy or war. Side-Channel Analysis in Hardware NI-HSC Z.ZK This course is dedicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attacks. Students get familiar with various kinds of side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and get familiar with higher-order attacks. They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel information leakage. NI-HMI2 History of Mathematics and Informatics ΖK 3 This course is presented in Czech. Selected topics {Infinitesimal calculus, probability, number theory, general algebra, different examples of algorithms, transformations, recursive functions, eliptic curves, etc.) note on possibilities of applications of some mathematical methods in informatics and its development. NI-IBE Information Security 2 Students learn information and IS/ICT security management systems (ISMS), methods for information access control, and basic norms and international standards in this area. They understand methods for management of internal and external security threats, for IS/IT security audits, and for application security testing (e.g., penetration testing) Intelligent embedded systems Intelligent embedded systems course for master's degree is focused on high-level technology embedded systems integrating artificial intelligence. The course is an advance version of the Intelligent embedded system fundamentals course for the bachelor degree. The aim of the course is to teach students humanoid robot programming and advance application development. Lectures provide basis of motion control, sensor reading, application interfaces, robot navigation and development tools. In labs, students develop advanced applications combining knowledge of various courses like nature inspired algorithms, data mining algorithms, image recognition and web technologies NI-IKM Internet and Classification Methods Z,ZK In this course, the students get acquainted with classification methods used in four important internet, or generally network applications; in spam filtering, in recommendation systems in malware detection systems and in intrusion detection systems. However, they will learn more than only how classification is performed when solving these four kinds of problems. On the background of these applications, they get an overview of the fundamentals of classification methods. The course is taught in a 2-weeks cycle with 2-hour lectures and 2-hour exercises. During the exercises, the students on the one hand implement simple examples to topics from the lectures, on the other hand consult their semester tasks. NI-IAM Internet and Multimedia The NI-IAM course is focused on principles and modern technologies for network transmissions of audiovisual (AV) signals. The syllabus includes acquisition of AV signals (input), presentation of AV signals (output), network communication protocols, device interfaces, codecs, data formats and stereoscopy. We will look at practical use case scenarios of real-time audiovisual transmissions. Within the labs, students will practically assemble AV transmission chains using HW and SW technologies and verify the effect of various components on the quality and latency of AV transmissions. Students will learn how to build Internet infrastructure for end-to-end AV transmissions from the recording the scene up to the presentation for audience. NI-IOT Internet of Things 7.7K 4 The subject is focused on the area of hardware and software technologies for the strongly growing computer support of various devices. Its goal is familiarization with available development elements (Raspberry Pi, Arduino Due) and with the language for efficient application development and modification (GNU Forth). Introduction to European Economic History The course introduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global economy through the description of the key periods in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the economic history. From large economic area of Roman Empire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial institutions is deciphered. The course does not cover detailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and organizations in history. Class meetings will consist of a mixture of lecture and discussion. Z.ZK NI-KTH Combinatorial Theories of Games Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory studies the behaviour of agents (players) of a certain competitive process by designinng a mathematical model and investigating the strategies. The traditional task of classical game theory is to find the equilibria, which are the states of the game where no player wants to deviate from his strategy. Historically, the second big development in game theory of two-player full-information combinatorial games, was by Conway, Berlekamp and Guy. They developed a theory, originally used for solving end-games in Go, into a full fledged field. The idea is to evaluate games such that otherwise incompatible games can be added, that is, played simultaneously. This led to the algrebraic approach to study combinatorial games. The third most important step is the work of Beck, who established the theory of positional games (like tic-tac-toe and hex). In analysis of these game, one cannot escape the brute-force traversal of the game tree, which is no efficient. Beck introduced the "false probabilistic method", which aims to tackhle this problem. In this course we build the foundation of the theory of combinatorial and positional games. We focus on theoretical analysis of games and building the theory, not on the programming aspects of game solving algorithms. The course requires independent work, ability to mathematically analyse, think and proof. The course is also suitable for bachelors student in the third year, who attended introduction to graph theory, as well as for PhD students looking for research topics. NI-FMT Finite model theory Z.ZK The aim of the course is to introduce students to the basics of finite model theory. The original motivation is the questions expressibility and verifiability of logical properties of database systems. Since its inception in the 1970s, the course has evolved rapidly and touched on many other areas of theoretical computer science, such as descriptive complexity theory, the Constraint Satisfaction Problem (CSP), the theory of algorithmic meta-theorems and combinatorics. NI-CCC Creative Coding and Computational Art ΚZ Students work on practical tasks, get acquainted with creative and yet proven methods of visualizing various types of data. The course freely follows the basic graphics courses (MGA, BLE,) and introduces students to suitable visualization methods for traditional as well as for open data. It combines well-known visualization techniques with artistic methods using modern technologies. The aim is to create an interesting visualization project. It is planned to work closely with IPR CAMP (Center of Architecture and Metropolitan Planning) and IIM (Institute of Intermedia FEL). Cybernality Students get acquainted with the fundamentals of legislation and international activities in the area of fighting cybercrime. Students will understand the classification of attacks and have an overview of systems for computer surveillance and traffic monitoring in the cyberspace. Students will also familiarize themselves with hacker activities and behavior. The course will also discuss the cooperation of the state agencies and subjects dealing with defence of the cyberspace (especially CSIRT and CERT teams). ΚZ Statistical Modelling Lab 5 The topic of LSM2 is advanced multiple target tracking (MTT). This domain covers simultaneous tracking of multiple targets using radar under the presence of clutter, or video tracking We aim at the state-of-the-art filters, in particular the PHD (Probability Hypothesis Density) and PMBM (Poisson Multi-Bernoulli) filters. NI-LOM Linear Optimization and Methods 7.7K Students learn the applications of optimization methods in computer science, economics, and industry. They are aware of practical importance of linear and integer programming. They are able to work with optimization software and are familiar with languages used in programming of that software. They get skills in formalization of optimization problems in computer science (such as scheduling of tasks to processors, analysis of network flows), distribution and allocation of resources (transportation problems, travelling salesman problems, etc.), issues from economics, and modelling of conflicts via the game theory. They get an overview of computational complexity of optimization problems. They get orientation in algorithms in linear programming. NI-MPL 2 Managerial Psychology ZK

NI-MSI			,
	Mathematical Structures in Computer Science   s of programming languages. Data types as continous lattices, Scott topology. Procedures as continuous mappings. The Scott	Z,ZK	4
Introduction to category		i model of lambd	a calculus.
NI-MZI	Mathematics for data science	Z,ZK	4
In this course, students	are introduced to those fields of mathematics that are necessary for understanding standard methods and algorithms used in		ne studied topics
•	gebra (matrix factorisations, eigenvalues, diagonalization), continuous optimisation (optimisation with constraints, duality principle)	ciple, gradient me	ethods) and
·	robability theory and statistics.		T
FIT-ITI	Modern IT infrastructure	Z,ZK	5
NI-MOP	Modern Object-Oriented Programming in Pharo	KZ	4
	mming is currently one of the most widespread paradigms of software creation, especially enterprise information systems, whe	-	
•	modern applications. In this course, we build on the knowledge acquired in the course BI-OOP and aim to further deepen the sladern pure object system Pharo (https://pharo.org). The course focuses on individual approach to students, their development	_	-
	bject programming skills, which are generally applicable in other OO languages, students will also gain the opportunity to wor		
technologies in terms of	f semestral work with the possibility of cooperation with practice and related bachelor, diploma, postgraduate our direct involved	ement in the Pha	ro Consortium.
NI-NLM	Neural Language Models	Z	5
	will learn the technical foundations of the Transformer architecture as well as the practical aspects of using language models.	The goal of the c	ourse is to teac
	nguage models to solve problems, make informed risk assessments, and work critically with the scientific literature.		1
NI-NMU	New media in art and design	ZK	3
	students to the issue of using new media in artistic and design work. Key topics are moving image, internet, computer game a		•
art projects.	with the largest possible range of creative approaches in new media. The subject emphasizes dialogue with students, especial	ily in lectures dev	otea to specific
NI-OLI	Linux Drivers	Z,ZK	4
_	term is an important operating system for personal computer and also for embedded systems. Systems on chip and combining	,	
	of peripheral subsystems requiring specific software drivers. This course is an advanced course in the Linux driver developme		
course provides knowle	edge of Linux operating system architecture, principles of development of various types drivers, including practical experience.		
NIE-PML	Personalized Machine Learning	Z,ZK	5
	earning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristic		
	ommonly used in applications such as recommender systems, which recommend items to users based on their personal inter		
	fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from the ly, we will focus on cutting-edge models that are of interest to both the research and commercial communities.	oretical, algorithr	nic, and practica
NI-ARI	Computer arithmetic	Z,ZK	4
	pus data representations used in digital devices and will be able to design arithmetic operations implementation units.	2,21	4
NI-PG1	Computer Grafics 1	ZK	4
	aphic courses (mainly BI-PGA and BI-PGR) and the knowledge from these courses is deepened by state-of-the-art knowledge.		
_	computer graphics. Students will gain practical knowledge with realistic texturing and raytracing methods. An integral part of the		-
articles and their subse	quent implementation. The course will be followed by a course PG2 supplementing the knowledge of PG1 on other areas and	topics of compu	ter graphics.
NI-EDW	Enterprise Data Warehouse Systems	Z,ZK	5
The Enterprise Data W	arehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods a		
Company and the Control of the Contr		and will gain prac	tical knowledge
, ,	arehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to		-
visualization.	arehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to	the area of repo	rting and data
visualization.  NI-PVR	arehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to  Advanced Virtual Reality	the area of repo	rting and data
visualization.  NI-PVR The course introduces	Advanced Virtual Reality  advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D mo	the area of repo	rting and data  4 and among othe
visualization.  NI-PVR The course introduces things, it introduces study	Advanced Virtual Reality  Advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will all	KZ dels in Blender, a	rting and data  4 and among othe ating applications
visualization.  NI-PVR The course introduces things, it introduces studin available 3D engines	Advanced Virtual Reality  advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D mo	KZ dels in Blender, a	rting and data  4 and among othe ating applications
visualization.  NI-PVR The course introduces things, it introduces studin available 3D engines	Advanced Virtual Reality advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will al (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the ctty create a complex game for VR.	KZ dels in Blender, a lso deal with crea	rting and data  4 and among othe ating applications ed in this subject
visualization.  NI-PVR The course introduces things, it introduces sturin available 3D engines in virtual reality, or direct NI-AML	Advanced Virtual Reality  advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will al (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the	KZ dels in Blender, a lso deal with crea knowledge gain Z,ZK	4 and among othe ating applications ed in this subject
visualization.  NI-PVR The course introduces things, it introduces sturin available 3D engines in virtual reality, or direct NI-AML The course introduces starting the starting of the startin	Advanced Virtual Reality advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will al (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the ctty create a complex game for VR.  Advanced machine learning	KZ dels in Blender, a lso deal with crea knowledge gain Z,ZK recommendation	4 and among othe ating application ed in this subject 5 a systems, image
visualization.  NI-PVR The course introduces things, it introduces sturing available 3D engines in virtual reality, or direct NI-AML The course introduces starting available 3D engines in virtual reality.	Advanced Virtual Reality advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will al (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the other accomplex game for VR.  Advanced machine learning students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of	KZ dels in Blender, a lso deal with crea knowledge gain Z,ZK recommendation	4 and among othe ating applications ed in this subject 5 a systems, image
visualization.  NI-PVR The course introduces things, it introduces studin available 3D engines in virtual reality, or direct NI-AML The course introduces a processing, control and NI-IOS Students will learn the	Advanced Virtual Reality advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will al (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the other accordance of the virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will all (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the other accordance of the virtual game worlds.  Advanced machine learning students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with the reality technology.	KZ dels in Blender, a lso deal with creating knowledge gain  Z,ZK recommendation methods discuss  KZ	4 and among othe atting applications ed in this subject 5 a systems, imaged.
visualization.  NI-PVR The course introduces things, it introduces studin available 3D engines in virtual reality, or direct NI-AML The course introduces processing, control and NI-IOS Students will learn the BI-IOS.	Advanced Virtual Reality advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will all (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the ctty create a complex game for VR.  Advanced machine learning students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with the real Advanced techniques in iOS applications atest trends in mobile development technologies for iOS platform. Class covers advanced topics, students need to know all the	KZ dels in Blender, a lso deal with crea knowledge gain  Z,ZK recommendation methods discuss KZ e basics from the	4 and among other atting applications ed in this subject 5 a systems, imaged.
visualization.  NI-PVR The course introduces things, it introduces sturing available 3D engines in virtual reality, or direct NI-AML The course introduces processing, control and NI-IOS Students will learn the BI-IOS.  NI-APT	Advanced Virtual Reality advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D modents to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will al (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the ctty create a complex game for VR.  Advanced machine learning students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with the real Advanced techniques in iOS applications atest trends in mobile development technologies for iOS platform. Class covers advanced topics, students need to know all the Advanced Program Testing	KZ dels in Blender, a lso deal with create knowledge gain  Z,ZK recommendation methods discuss KZ e basics from the	4 and among other atting application ed in this subject 5 a systems, imaged.  4 beginners clas
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NI-PSL The course introduces to			
The course introduces	Programming in Scala	Z,ZK	4
	he modern programming language Scala which exploits object-functional paradigm. Scala comprises advance language feature		
	y. Scala enables to use of applications functional patterns e.g. H-List, Monads, etc. Scala is used by many powerful frameworks a	and libraries e.g. F	Play, Cassandra,
Scalaz, etc.	Description in Duke.	1/7	
NI-RUB	Programming in Ruby	KZ	4
This course is presente		7.71	
NI-ROZ	Pattern Recognition	Z,ZK	
	s to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the st		
	ill learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, and		
NI-PLS1	Programming Language Seminar	Z	2
	uage Seminar aims to introduce students to research in programming languages. It has the format of a reading group in whicl guages and related fields. Participating students are expected to present a paper of their interest and actively participate in the		
	n FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.	e discussions. Th	e reading group
NI-PLS2		7	2
	Programming Language Seminar   uage Seminar aims to introduce students to research in programming languages. It has the format of a reading group in whicl		
	guages and related fields. Participating students are expected to present a paper of their interest and actively participate in the		
	n FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.	o dioodooiono. Tri	o rodding group
NI-PLS3	Programming Language Seminar	7	2
	uage Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which	_	
	guages and related fields. Participating students are expected to present a paper of their interest and actively participate in the		
	n FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.		
NI-PLS4	Programming Language Seminar	Z	2
_	uage Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which	h we discuss scie	
	guages and related fields. Participating students are expected to present a paper of their interest and actively participate in the		
is a joint venue between	n FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.		
NI-SCE1	Computer Engineering Seminar Master I	Z	4
The Seminar of Compu	rer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance	e to failures and a	ttacks. Students
are approached individe	ually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the	ne subject is work	with scientific
articles and other profe	ssional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar teach	hers. The topics a	are new for each
semester.			
NI-SCE2	Computer Engineering Seminar Master II	Z	4
•	er Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance		
are approached individu	ually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the	ne subject is work	with scientific
· · · · · · · · · · · · · · · · · · ·	ssional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar teach	hers. The topics a	are new for each
semester.			
NI-SZ1	Knowledge Engineering Seminar Master I	Z	4
•	I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top resear		
	rn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top mac	chine learning and	d Al conferences
	s well as FIT's own Summer Research Program (VyLet).	7	
NI-SZ2	Knowledge Engineering Seminar Master II	Z	4
NI-SZ2 On this seminar you wil	Knowledge Engineering Seminar Master II present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top resear	rch labs around t	he world.
NI-SZ2 On this seminar you will Additionally, you will lea	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made	rch labs around t	he world.
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NI-SZ2 On this seminar you will Additionally, you will lea and summer schools, a PI-SCN	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top mades well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design	rch labs around to	he world. d Al conferences
NI-SZ2 On this seminar you wil Additionally, you will lea and summer schools, a PI-SCN This subject deals with	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top mades well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description	rch labs around to chine learning and ZK of digital circuits	he world. d AI conferences  4 and basic logic
NI-SZ2 On this seminar you will Additionally, you will lea and summer schools, a PI-SCN This subject deals with synthesis and optimizat	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description ion algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial p	rch labs around the chine learning and ZK of digital circuits roblems emergin	he world. d Al conferences  4 and basic logic g in EDA.
NI-SZ2 On this seminar you will Additionally, you will lea and summer schools, a PI-SCN This subject deals with synthesis and optimizat NI-MLP	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description ion algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial p  Machine Learning in Practice	rch labs around the chine learning and ZK of digital circuits roblems emergin Z,ZK	the world.  d Al conferences  4  and basic logic g in EDA.
NI-SZ2 On this seminar you will lea and summer schools, a PI-SCN This subject deals with synthesis and optimizat NI-MLP Applying machine learn	Knowledge Engineering Seminar Master II  present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description ion algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial p  Machine Learning in Practice  ing methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to,	rch labs around the chine learning and the chine learning and the chine learning and the chine learning around the chine l	d Al conferences  4 and basic logic g in EDA.  5 implementation.
NI-SZ2 On this seminar you will Additionally, you will lea and summer schools, a PI-SCN This subject deals with synthesis and optimizat NI-MLP Applying machine learn The course guides study	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description ion algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial p  Machine Learning in Practice  ing methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to, ents through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practice	rch labs around the shine learning and ZK of digital circuits roblems emergin Z,ZK ideally, technical ally. The aim is to	d Al conferences  4 and basic logic g in EDA.  5 implementation. experience real
NI-SZ2 On this seminar you will Additionally, you will lea and summer schools, a PI-SCN This subject deals with synthesis and optimizat NI-MLP Applying machine learn The course guides studdata processing and lea	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made is well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description ion algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial p  Machine Learning in Practice  ing methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to, ents through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practice are how to describe the whole process from exploration to evaluation of the model performance in the form of a clear and understand i	rch labs around the chine learning and the chine learning ally. The aim is to the cerstandable reportant and the chine learning and the c	d Al conferences  4 and basic logic g in EDA. 5 implementation. experience real rt.
NI-SZ2 On this seminar you will Additionally, you will lea and summer schools, at PI-SCN This subject deals with synthesis and optimizate NI-MLP Applying machine learn The course guides studdata processing and least BI-ML1.21	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top resear in how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made is well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description ion algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial part Machine Learning in Practice  ing methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to, ents through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practice arm how to describe the whole process from exploration to evaluation of the model performance in the form of a clear and under Machine Learning 1	zk of digital circuits roblems emergin Z,ZK ideally, technical ally. The aim is to erstandable repo Z,ZK	the world.  d Al conferences  4  and basic logic g in EDA.  5  implementation. experience real rt.  5
NI-SZ2 On this seminar you will Additionally, you will lea and summer schools, a PI-SCN This subject deals with synthesis and optimizat NI-MLP Applying machine learn The course guides stud data processing and lea BI-ML1.21 The goal of this course	Knowledge Engineering Seminar Master II  I present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top resear in how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top made is well as FIT's own Summer Research Program (VyLet).  Seminars on Digital Design  problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description ion algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial particle ing methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to, ents through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practice arm how to describe the whole process from exploration to evaluation of the model performance in the form of a clear and under Machine Learning 1  is to introduce students to the basic methods of machine learning. They get theoretical understanding and practical working keeps a second of the process in the proof of the model performance in the form of a clear and understanding and practical working keeps and the process in the process	rch labs around the chine learning and the ch	the world.  d Al conferences  4  and basic logic g in EDA.  5  implementation. experience real rt.  5  ession and
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NI-TS1 Theoretical Seminar Master I Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar. Theoretical Seminar Master II Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar. Theoretical Seminar Master III Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar. NI-TS4 Theoretical Seminar Master IV Theoretical seminar is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classical reading group. The students are treated individually and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a work with scientific papers and other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar. NI-TKA Category Theory Z,ZK 4 Theory of Neural Networks Z,ZK In this course, we study neural networks from the point of view of the theory of function approximation and from the point of view of probability theory. At first, we recall basic concepts pertaining to artificial neural Networks, such as neurons and connections between them, types of neurons from the point of view of signal transmission, network topology, somatic and synaptic mappings, network training, and the role of time in neural networks. In connection with network topology, we get acquainted with its transformation into a canonical topology, and in connection with somatic and synaptic mappings, with their composition into mappings computed by the Network, Finally in connection with training, we pay attention to the problem of overtraining and to the fact that training is actually a specific optimization task, recalling the most typical objective functions and the most important optimization methods employed for neural network training. We will see the meaninig of all these concepts in the context of common kinds of forward neural networks. Within the topic approximation approach to neural networks, we first notice the connection of neural networks to expressing functions of many variables using functions of fewer variables (Kolmogorov theorem, Vituškin theorem). Afterwards, we will see how the universal approximation capacity of neural networks can be mathematically formalized as the sets of mappings computed by neural networks being dense in important Banach spaces of functions, in particular in the spaces of continuous functions, spaces of functions integrable with respect to a finite measure, spaces of functions with continuous derivatives, and Sobolev spaces. Within the topic probabilistic approach, we first get acquainted with training based on expectation and training based on a random sample, and with probabilistic assumptions about training data with which those two kinds of neural networks can be employed. We will see how it is possible to get an estimate of the conditional expectancy of network outputs conditioned by its inputs using the expectancy based learning. We recall the strong and the weak law of large numbers and get acquainted with an analogy of the strong law of large numbers for neural networks and with the assumptions for its validity. Finally, we recall the central limit theorem, get acquinted with its analogy for neural networks, with the assumptions for its validity and with the hypothesis tests based on it. We will see how those tests can be employed to search for the topology of the network. Z,ZK NI-CPX Complexity Theory 5 Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems Academic writing Publishing is an important and required part of research activity. It is not only about obtaining research results but also about applying them in the form of publication. Writing scientific publications can be useful for students not only in their own publishing activities but also in the preparation of a bachelor's or master's thesis. In the course, students will learn how to write a scientific article, what parts such an article should have, and how the peer review process works. Students will also try their hand at presenting an article and reviewing someone else's article. The course will be taught in blocks, with one lecture at the beginning of the semester and one practicum in the middle of the semester. Dates will be determined based on the availability of enrolled students. NI-DVG Introduction to Discrete and Computational Geometry Z,ZK 5 The course intends to introduce the students to the discipline of Discrete and Computational Geometry. The main goal of the course is to get familiar with the most fundamental notions of this discipline, and to be able to solve simple algorithmic problems with a geometric component. NI-VOL Z,ZK 5 Elections We will cover the basics of (committee) elections and, in general, opinion aggregation. NI-VYC Z.ZK 4 Computability Classical theory of recursive functions and effective computability. NI-VPR Research Project Ζ 5 Student obtains the credits for published scientific outputs. The details are at https://courses.fit.cvut.cz/NI-VPR/en. NI-ZS10 Master internship abroad for 10 credits Ζ 10 Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line. NI-ZS20 Master internship abroad for 20 credits Ζ 20 Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic vear's dead-line. NI-ZS30 Z 30 Master internship abroad for 30 credits The course is prezented in chzech language. Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line.

# List of courses of this pass:

	·		
Code	Name of the course	Completion	Credits
BI-ML1.21	Machine Learning 1	Z,ZK	5
=	s course is to introduce students to the basic methods of machine learning. They get theoretical understanding and practical working k		
	odels in the supervised learning scenario and clustering models in the unsupervised scenario. Students will be aware of the relationsh	•	
variance, and kno	w the fundamentals of assessing model quality. Moreover, they learn the basic techniques of data preprocessing and multidimensiona demonstrations, pandas and scikit libraries in Python will be used.	i data visualization.	. in practica
BI-ML2.21	Machine Learning 2	Z,ZK	5
	INTACTIFIE LEARTHING 2 course is to introduce students to the selected advanced methods of machine learning. In the supervised learning scenario, they, in pa		_
•	orks. In the unsupervised learning scenario students learn the principal component analysis and other dimensionality reduction metho		
	basic principles of reinforcement learning and natural language processing.	20	and got and
FI-TOP	Academic writing	Z	2
	nportant and required part of research activity. It is not only about obtaining research results but also about applying them in the form	- 1	l
publications can l	be useful for students not only in their own publishing activities but also in the preparation of a bachelor's or master's thesis. In the cou	ırse, students will le	earn how to
write a scientific a	rticle, what parts such an article should have, and how the peer review process works. Students will also try their hand at presenting an	article and reviewing	ng someone
else's article. The	e course will be taught in blocks, with one lecture at the beginning of the semester and one practicum in the middle of the semester. D	ates will be determi	ined based
	on the availability of enrolled students.		1
FIT-ITI	Modern IT infrastructure	Z,ZK	5
FIT-SEP	World Economy and Business	Z,ZK	4
This course is pr	resented in Czech. The course introduces students of technical university to the international business. It does that predominantly by c	omparing individua	l countries
	f world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as		
corruption and ec	onomic development, which are needed for the right investment decision. Seminars help to improve on the knowledge in the form of d	iscussions based o	n individual
	readings. It is advised to take bachelor level of this course BIE-SEP as a prerequisite.		
FITE-EHD	Introduction to European Economic History	Z,ZK	3
	duces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global eco		-
	Is in history. As European countries have been dominant actors in this process it focuses predominantly on their roles in the economic		
	mpire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial institut letailed economic history of particular European countries but rather the impact of trade and role of particular events, institutions and o	=	
does not cover d	meetings will consist of a mixture of lecture and discussion.	ngamzations in ms	tory. Class
NI-AFP	Applied Functional Programming	KZ	5
	sented in Czech. Functional programming represents one of the traditional programming paradigms. Traditional and novel functional programming represents one of the traditional programming paradigms.	1	_
	s and the functional paradigm becomes an important construct of traditionally imperative languages (C++, C#, Java). As such, maste		_
•	necessary competence of a software engineer: the theory and especially the practice.		
NI-AML	Advanced machine learning	Z,ZK	5
The course introdu	uces students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of re-	1 ' 1	ems, image
processing	, control and interconnection of physical laws with the field of machine learning. The aim of the exercise is to familiarize students with	the methods discus	ssed.
NI-AOA	Completing a professional event	Z	1
The subject is par	ricipation in a one-off professional event, usually a lecture by a foreign guest of the FIT CTU, concluded with a workshop, a test, draft	ng a report, etc.Su	ch an event
must be approve	ed in advance by the vice-dean for pedagogical activities or the vice-dean for science and research and is presented within the FIT thr	ough a website, info	omail, etc.
NI-APH	Architecture of computer games	Z,ZK	4
_	a basic understanding of the various issues in the field of computer games development, especially from a technical point of view, but also		-
	will get a grasp of component-oriented and functional-oriented architecture, game mechanics, decision-making processes and base co	•	•
part of most gan	nes. They will also understand the basics of pathfinding, networking and scripting and apply them in practical exercises (labs). An improvementation of a simple game, with a strong feature of participal game, machanism	ortant part of the co	iurse is an
NII ADT	implementation of a simple game, with a strong focus on nontrivial game mechanics.	7 71/	
NI-APT	Advanced Program Testing  m is essential to ensure that a program respects its specification, that changes do not introduce regressions or security issues. The gr	Z,ZK	5
resurig a progra	advanced program testing techniques, beyond writing unit tests, especially fuzzing and symbolic execution.	di di the course is	to present
NI-ARI		Z,ZK	4
INI-AKI	Computer arithmetic  Students will learn various data representations used in digital devices and will be able to design arithmetic operations implementate		4
NI-ATH	AlgorithmicTheories of Games	Z,ZK	4
	e theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory stu	1 ' 1	l
_	rtain competitive process by designinng a mathematical model and investigating the strategies. The traditional task of classical game		_
	es of the game where no player wants to deviate from his strategy. Due to the recent development of computers, internet, social network	=	-
	ns and other concepts the algorithmic point of view is gaining attention. In addition to existential questions we study the problems of e		_
	n concepts. In this course we introduce the basics of game theory of many players, solution concept (usually equilibria) and methods of	•	
NI-BPS	Wireless Computer Networks	Z,ZK	4
	rn about the modern technologies, protocols, and standards for wireless networks. They will understand the routing mechanisms in ac	1	l
	anisms, and data flow control mechanisms. They will also learn about principles of communication in sensor networks. They get knowl		
	for wireless networks and get skills of configuration of wireless network elements and simulation of wireless networks using suital	ole tools.	
NI-CCC	Creative Coding and Computational Art	KZ	4
	practical tasks, get acquainted with creative and yet proven methods of visualizing various types of data. The course freely follows the		rses (MGA
BLE,) and introd	duces students to suitable visualization methods for traditional as well as for open data. It combines well-known visualization technique	s with artistic meth	ods using
modern technolog	gies. The aim is to create an interesting visualization project. It is planned to work closely with IPR CAMP (Center of Architecture and I	Metropolitan Planni	ng) and IIM
	(Institute of Intermedia FEL).		

NI-CPX	Complexity Theory	Z,ZK	5
Students will lear	n about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the	theory concerning	g practical
	(in)tractability of difficult problems.		
NI-CTF	Capture The Flag	KZ	4
	The course is designed to introduce students to CTF competitions and let them gain practical experience in the field of cyber see		
NI-DDM	Distributed Data Mining	KZ	4
	state-of-the-art approaches for distributed data mining and parallelization of machine learning algorithms. Students will gain hands o	•	-
data processing fra	amework Apache Spark and with existing distributed DM / ML algorithms. They will learn principles of their parallel implementations at	nd will be capable	to propose
AII DID	approaches to parallelize other algorithms. The course is prezented in czech language.		
NI-DID	Digital drawing	Z	2
	oduce students to the basic principals of digital drawing and graphical design. Students will gain understanding of composition, persp apply in their own design works. Students will also gain experience in drawing and painting with digital and analog tools. The course		-
	learn drawing and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practic	•	
NI-DNP	Advanced .NET	Z.ZK	4
	ا re an overview of platform .NET and will gain knowledge about technologies ASP.NET Core, Entity Framework Core, .NET MAUI (WF	, ,	-
· · · · · · · · · · · · · · · · · · ·	re DevOps and GIT. Students will get practical experience in semestral work where they will create a client-server application utilizing	•	
got notions of 712a.	Entity Framework Core and (Blazor, .NET MAUI or WPF) and also Azure DevOps and GIT.	1001111010g1007101	
NI-DPH	Game Design	Z,ZK	5
	ments the NI-APH (Architecture of Computer Games) and BI-VHS (Virtual gaming worlds) course, while focusing primarily on game d	· '	-
	er knowledge of the principles used for games design, such as: level design, gameplay design, character design, game mechanics de	-	
development cycle.	The students will get an overview of game development from the designer's perspective, from theoretical concepts to practical implementation of the students will get an overview of game development from the designer's perspective, from theoretical concepts to practical implementation of the students will get an overview of game development from the designer's perspective, from theoretical concepts to practical implementation of the students of the students will get an overview of game development from the designer's perspective, from the students will get an overview of game development from the designer's perspective, from the students will get an overview of game development from the designer's perspective, from the students will get an overview of game development from the designer's perspective from the students will be supported by the students of the students	nentation applied t	o semestral
	projects.		
NI-DSW	Design Sprint	Z	2
	on projects using the Design Sprint method, developed by Google. THanks to this method the teams are able to go from idea to validat		
the course the stu	dents will get familiar with the method as participants. Through practical challenges they will try the whole 5 day process starting with	research and fini	shing with
	testing the prototypes (plus final presentation).		
NI-DVG	Introduction to Discrete and Computational Geometry	Z,ZK	5
The course intends	to introduce the students to the discipline of Discrete and Computational Geometry. The main goal of the course is to get familiar with	the most fundame	ntal notions
	of this discipline, and to be able to solve simple algorithmic problems with a geometric component.		
NI-DZO	Digital Image Processing	Z,ZK	4
	nts a comprehensive overview of modern methods for interactive editing of digital images and video. It mainly deals with practical alg		-
	e an interesting theoretical basis. Visually attractive applications provide better understanding of basic theoretical background that is als		
	processing. This course will introduce algorithms solving the following practical applications: edge-aware editing, tone mapping, HDR of the processing of the processing digital photo mapping, and the processing digital photo mapping color to gray convergence of the processing digital photo mapping.	-	-
mequency domain,	abstraction, hybrid images, gradient domain editing, seamless image stitching and cloning, digital photo-montage, color-to-gray converged to the converged to the converged converged to the c	ersion, context em	iancement,
interactive as-ri	nid-as-nossible image deformation, free-form image registration, texture synthesis, interactive segmentation, colorization, painting, ad-	lding denth, alpha	
	gid-as-possible image deformation, free-form image registration, texture synthesis, interactive segmentation, colorization, painting, ad		matting.
NI-EDW	Enterprise Data Warehouse Systems	Z,ZK	matting.
NI-EDW The Enterprise Da	Enterprise Data Warehouse Systems ta Warehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods and	Z,ZK will gain practical	matting. 5 knowledge
NI-EDW The Enterprise Da	Enterprise Data Warehouse Systems	Z,ZK will gain practical	matting. 5 knowledge
NI-EDW The Enterprise Da	Enterprise Data Warehouse Systems ta Warehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods and ing warehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to the	Z,ZK will gain practical	matting. 5 knowledge
NI-EDW The Enterprise Da not only in design NI-ESC	Enterprise Data Warehouse Systems ta Warehouses course focuses on the area of business intelligence. Students will be introduced to business intelligence methods and ing warehouses and various architectures, but also their deployment and maintenance. This course also includes an introduction to the visualization.	Z,ZK I will gain practical ne area of reporting KZ	matting. 5 knowledge g and data 8
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NI-IAM Internet and Multimedia Z,ZK The NI-IAM course is focused on principles and modern technologies for network transmissions of audiovisual (AV) signals. The syllabus includes acquisition of AV signals (input), presentation of AV signals (output), network communication protocols, device interfaces, codecs, data formats and stereoscopy. We will look at practical use case scenarios of real-time audiovisual transmissions. Within the labs, students will practically assemble AV transmission chains using HW and SW technologies and verify the effect of various components on the quality and latency of AV transmissions. Students will learn how to build Internet infrastructure for end-to-end AV transmissions from the recording the scene up to the presentation for audience NI-IBE ZK Information Security Students learn information and IS/ICT security management systems (ISMS), methods for information access control, and basic norms and international standards in this area. They understand methods for management of internal and external security threats, for IS/IT security audits, and for application security testing (e.g., penetration testing). Internet and Classification Methods NI-IKM In this course, the students get acquainted with classification methods used in four important internet, or generally network applications: in spam filtering, in recommendation systems, in malware detection systems and in intrusion detection systems. However, they will learn more than only how classification is performed when solving these four kinds of problems. On the background of these applications, they get an overview of the fundamentals of classification methods. The course is taught in a 2-weeks cycle with 2-hour lectures and 2-hour exercises. During the exercises, the students on the one hand implement simple examples to topics from the lectures, on the other hand consult their semester tasks Advanced techniques in iOS applications Students will learn the latest trends in mobile development technologies for iOS platform. Class covers advanced topics, students need to know all the basics from the beginners class BI-IOS. NI-IOT Internet of Things Z,ZK 4 The subject is focused on the area of hardware and software technologies for the strongly growing computer support of various devices. Its goal is familiarization with available development elements (Raspberry Pi, Arduino Due) and with the language for efficient application development and modification (GNU Forth). NI-IVS Intelligent embedded systems ΚZ Intelligent embedded systems course for master's degree is focused on high-level technology embedded systems integrating artificial intelligence. The course is an advance version of the Intelligent embedded system fundamentals course for the bachelor degree. The aim of the course is to teach students humanoid robot programming and advance application development. Lectures provide basis of motion control, sensor reading, application interfaces, robot navigation and development tools. In labs, students develop advanced applications combining knowledge of various courses like nature inspired algorithms, data mining algorithms, image recognition and web technologies Combinatorial Theories of Games NI-KTH Traditional game theory is a branch of mathematics, which has broad applications in economy, biology, politics and computer science. This theory studies the behaviour of agents (players) of a certain competitive process by designing a mathematical model and investigating the strategies. The traditional task of classical game theory is to find the equilibria, which are the states of the game where no player wants to deviate from his strategy. Historically, the second big development in game theory of two-player full-information combinatorial games, was by Conway, Berlekamp and Guy. They developed a theory, originally used for solving end-games in Go, into a full fledged field. The idea is to evaluate games such that otherwise incompatible games can be added, that is, played simultaneously. This led to the algrebraic approach to study combinatorial games. The third most important step is the work of Beck, who established the theory of positional games (like tic-tac-toe and hex). In analysis of these game, one cannot escape the brute-force traversal of the game tree, which is no efficient. Beck introduced the "false probabilistic method", which aims to tackhle this problem. In this course we build the foundation of the theory of combinatorial and positional games. We focus on theoretical analysis of games and building the theory, not on the programming aspects of game solving algorithms. The course requires independent work, ability to mathematically analyse, think and proof. The course is also suitable for bachelors student in the third year, who attended introduction to graph theory, as well as for PhD students looking for research topics. NI-KYB Cybernality ZK Students get acquainted with the fundamentals of legislation and international activities in the area of fighting cybercrime. Students will understand the classification of attacks and have an overview of systems for computer surveillance and traffic monitoring in the cyberspace. Students will also familiarize themselves with hacker activities and behavior. The course will also discuss the cooperation of the state agencies and subjects dealing with defence of the cyberspace (especially CSIRT and CERT teams). NI-LOM Linear Optimization and Methods Students learn the applications of optimization methods in computer science, economics, and industry. They are aware of practical importance of linear and integer programming. They are able to work with optimization software and are familiar with languages used in programming of that software. They get skills in formalization of optimization problems in computer science (such as scheduling of tasks to processors, analysis of network flows), distribution and allocation of resources (transportation problems, travelling salesman problems, etc.), issues from economics, and modelling of conflicts via the game theory. They get an overview of computational complexity of optimization problems. They get orientation in algorithms in linear programming. NI-LSM2 Statistical Modelling Lab 5 The topic of LSM2 is advanced multiple target tracking (MTT). This domain covers simultaneous tracking of multiple targets using radar under the presence of clutter, or video tracking. We aim at the state-of-the-art filters, in particular the PHD (Probability Hypothesis Density) and PMBM (Poisson Multi-Bernoulli) filters. NI-MLP Machine Learning in Practice Applying machine learning methods to real projects in practice involves many other necessary tasks - from understanding the intentions of the client to, ideally, technical implementation. The course guides students through all phases of a project according to the standard CRISP-DM methodology, not only theoretically but also practically. The aim is to experience real data processing and learn how to describe the whole process from exploration to evaluation of the model performance in the form of a clear and understandable report. Modern Object-Oriented Programming in Pharo NI-MOP ΚZ Object-oriented programming is currently one of the most widespread paradigms of software creation, especially enterprise information systems, where its ability to natural abstraction is used to build complex modern applications. In this course, we build on the knowledge acquired in the course BI-OOP and aim to further deepen the skills of design and implementation of object systems in modern pure object system Pharo (https://pharo.org). The course focuses on individual approach to students, their development needs and areas of interest. In addition to deepening object programming skills, which are generally applicable in other OO languages, students will also gain the opportunity to work on interesting projects and OO technologies in terms of semestral work with the possibility of cooperation with practice and related bachelor, diploma, postgraduate our direct involvement in the Pharo Consortium. NI-MPL Managerial Psychology 7K 2 NI-MSI Mathematical Structures in Computer Science Z,ZK 4 Mathematical semantics of programming languages. Data types as continous lattices, Scott topology. Procedures as continuous mappings. The Scott model of lambda calculus. Introduction to category theory. Mathematics for data science In this course, students are introduced to those fields of mathematics that are necessary for understanding standard methods and algorithms used in data science. The studied topics include mainly: linear algebra (matrix factorisations, eigenvalues, diagonalization), continuous optimisation (optimisation with constraints, duality principle, gradient methods) and selected notions from probability theory and statistics. Neural Language Models In this course, students will learn the technical foundations of the Transformer architecture as well as the practical aspects of using language models. The goal of the course is to teach students how to use language models to solve problems, make informed risk assessments, and work critically with the scientific literature.

NI-NMU	New media in art and design	ZK	3
	uces students to the issue of using new media in artistic and design work. Key topics are moving image, internet, computer game an		-
familiarize the stud	ent with the largest possible range of creative approaches in new media. The subject emphasizes dialogue with students, especially in the largest possible range of creative approaches in new media. The subject emphasizes dialogue with students, especially in the largest possible range of creative approaches in new media.	n lectures devoted	to specific
NI-OLI	art projects.  Linux Drivers	Z,ZK	4
	g system is an important operating system for personal computer and also for embedded systems. Systems on chip and combining po		
	ability of peripheral subsystems requiring specific software drivers. This course is an advanced course in the Linux driver development		
	urse provides knowledge of Linux operating system architecture, principles of development of various types drivers, including practica	al experience.	
_ NI-PAM	Efficient Preprocessing and Parameterized Algorithms	Z,ZK	4
	optimization problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often necess We will demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often one		
	nputs from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity exponer		
	the input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomial times.		
	ible in the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent solution		·
	eterized algorithm design methods and we will also show how to prove that for some problem (and parameter) such an algorithm (pre will also not miss out the relations to other approaches to hard problems such as moderately exponential algorithms or approximatior		t exist. We
NI-PG1	Computer Grafics 1	ZK	4
-	ا n graphic courses (mainly BI-PGA and BI-PGR) and the knowledge from these courses is deepened by state-of-the-art knowledge. Th		
	ced computer graphics. Students will gain practical knowledge with realistic texturing and raytracing methods. An integral part of the c	-	
articles and their	subsequent implementation. The course will be followed by a course PG2 supplementing the knowledge of PG1 on other areas and t	opics of computer	graphics.
NI-PLS1	Programming Language Seminar	Z	2
	Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which I languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the d		
about programming	i ranguages and related fields. Participating students are expected to present a paper of their interest and actively participate in the dispersion is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages.		auing group
NI-PLS2	Programming Language Seminar	Z	2
The Programming	Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which	we discuss scienti	ific papers
about programming	languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the d		ading group
NII DI OO	is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages		
NI-PLS3	Programming Language Seminar  Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which	Z	2
	I languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the di		
	is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages		
NI-PLS4	Programming Language Seminar	Z	2
	Language Seminar aims to introduce students to research in programming languages. It has the format of a reading group in which		
about programming	languages and related fields. Participating students are expected to present a paper of their interest and actively participate in the di	iscussions. The rea	adina aroun l
	is a joint venue between FIT and MEE CLINI. It is open to all students and researchers interested in programming language		during group
NI-PSD	is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages	3.	
NI-PSD The course will intro	is a joint venue between FIT and MFF CUNI. It is open to all students and researchers interested in programming languages  Public Services Design  oduce students to specifics of UX, Service design and development for public sector. We will look into the design and development programming languages.	s. KZ	4
The course will intro	Public Services Design  oduce students to specifics of UX, Service design and development for public sector. We will look into the design and development pr  nd designesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration	KZ rocess from the pe	4 rspective of
The course will intro suppliers (devs a	Public Services Design  oduce students to specifics of UX, Service design and development for public sector. We will look into the design and development pr  nd designesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration  Course is aimed at students-designers as well as clients.	KZ rocess from the pe	4 erspective of entatives.
The course will intro suppliers (devs a	Public Services Design oduce students to specifics of UX, Service design and development for public sector. We will look into the design and development pr nd designesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration Course is aimed at students-designers as well as clients.  Programming in Scala	KZ ocess from the pe o with client repres	4 rspective of entatives.
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The course will intra suppliers (devs a NI-PSL The course introduce advance standard liance introduces in available 3D enging available 3D enging NI-PVS The course is focus working with mass  NI-PYT The goal of this convery hands-on and NI-ROZ The aim of the mass recognition. Stuniance NI-RUB  NI-SCE1 The Seminar of Corare approached incomplete in the supplier of	Public Services Design  aduce students to specifics of UX, Service design and development for public sector. We will look into the design and development pr  and designesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration  Course is aimed at students-designers as well as clients.  Programming in Scala  uses the modern programming language Scala which exploits object-functional paradigm. Scala comprises advance language feature brary. Scala enables to use of applications functional patterns e.g. H-List, Monads, etc. Scala is used by many powerful frameworks and  Scalaz, etc.  Advanced Virtual Reality  ses advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D models students to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will also  nes (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the kn  in virtual reality, or directly create a complex game for VR.  Advanced embedded systems  sed on ARM processors and microcontrollers and their usage in wide range of applications. The course includes a series of advance  storage devices, motor control, system control and industrial communication. The students obtain both theoretical and also practical systems.  Advanced Python  urse is to learn various advanced techniques and methods in Python. The course indirectly continues where Programming in Python  it has only tutorials, everything is demonstrated on examples. Classification is based on work in class as well as semestral coursework.  teachers from Red Hat.  Pattern Recognition  odule is to give a systematic account of the major topics in pattern recognition, including probability models, parameter estimation, ar  Programming in Ruby  This course is presented in Czech.  Computer Engineering Seminar Master I  muter Engin	s. KZ cocess from the per or with client representation of the period of	4 respective of entatives.  4 the thing and Cassandra,  4 among other applications this subject  4 the subject of the thing and the thing and the thing and the thing and the thing applications this subject of the thing applications are the thing and the thing applications the thing and the thing are the thing and the thing are the thing and the thing are the thing
The course will intra suppliers (devs a NI-PSL The course introduce advance standard liance in the course introduces in available 3D enging available 3D enging NI-PVS The course is focus working with mass  NI-PYT The goal of this convery hands-on and NI-ROZ The aim of the mass recognition. Stungler NI-SCE1 The Seminar of Conare approached in articles and other personners.	Public Services Design  aduce students to specifics of UX, Service design and development for public sector. We will look into the design and development prince designes; as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration.  Course is aimed at students-designers as well as clients.  Programming in Scala  uces the modern programming language Scala which exploits object-functional paradigm. Scala comprises advance language features brary. Scala enables to use of applications functional patterns e.g. H-List, Monads, etc. Scala is used by many powerful frameworks and Scalaz, etc.  Advanced Virtual Reality  ces advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D model students to their application in virtual reality. Lectures will flocus on virtual reality technology, its use in various applications and will also ines (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the kn in virtual reality, or directly create a complex game for VR.  Advanced embedded systems  sed on ARM processors and microcontrollers and their usage in wide range of applications. The course includes a series of advance is storage devices, motor control, system control and industrial communication. The students obtain both theoretical and also practical systems.  Advanced Python  urse is to learn various advanced techniques and methods in Python. The course indirectly continues where Programming in Python it has only tutorials, everything is demonstrated on examples. Classification is based on work in class as well as semestral coursework. teachers from Red Hat.  Pattern Recognition  odule is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the stadents will learn the fundamental concepts and methods of pattern recognition with emphasis on problems and applic	s. KZ cocess from the per or with client representation of the period with client representation of the period with client representation of the period with creating and a deal with creating and a	4 respective of entatives.  4 stching and Cassandra,  4 smong other applications this subject  4 sity support, embedded  4 se course is 1 by external  5 so pattern aspects.  4 ss. Students th scientific ew for each
The course will intra suppliers (devs a NI-PSL The course introduce advance standard liance introduces in available 3D enging available 3D enging in available 3	Public Services Design  aduce students to specifics of UX, Service design and development for public sector. We will look into the design and development pr  and designesr) as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration  Course is aimed at students-designers as well as clients.  Programming in Scala  uses the modern programming language Scala which exploits object-functional paradigm. Scala comprises advance language feature brary. Scala enables to use of applications functional patterns e.g. H-List, Monads, etc. Scala is used by many powerful frameworks and  Scalaz, etc.  Advanced Virtual Reality  ses advanced parts of the virtual reality. It is a continuation of the already running graphic objects, especially the creation of 3D models students to their application in virtual reality. Lectures will focus on virtual reality technology, its use in various applications and will also  nes (mainly Unity3D). The course is freely connected with the subject VHS (virtual game worlds), students will be able to apply the kn  in virtual reality, or directly create a complex game for VR.  Advanced embedded systems  sed on ARM processors and microcontrollers and their usage in wide range of applications. The course includes a series of advance  storage devices, motor control, system control and industrial communication. The students obtain both theoretical and also practical systems.  Advanced Python  urse is to learn various advanced techniques and methods in Python. The course indirectly continues where Programming in Python  it has only tutorials, everything is demonstrated on examples. Classification is based on work in class as well as semestral coursework.  teachers from Red Hat.  Pattern Recognition  odule is to give a systematic account of the major topics in pattern recognition, including probability models, parameter estimation, ar  Programming in Ruby  This course is presented in Czech.  Computer Engineering Seminar Master I  muter Engin	s. KZ cocess from the per or with client representation of the period of	4 respective of entatives.  4 the thing and Cassandra,  4 among other applications this subject  4 the subject of the thing and the thing and the thing and the thing applications this subject of the thing applications the the thing and the thing and the thing and the thing applications the thing and the thing are
The course will intra suppliers (devs a NI-PSL The course introduces advance standard liance introduces in available 3D enging available 3D enging in available	Public Services Design  aduce students to specifics of UX, Service design and development for public sector. We will look into the design and development prince of the design and sevelopment prince of the designers as well as clients. In small teams students will work on projects from partner organizations and will try out collaboration. Course is aimed at students-designers as well as clients.  Programming in Scala  Description of the work of the work of the state of the design of the state of	KZ ocess from the per or with client representation of the period of the	4 respective of entatives.  4 stching and Cassandra,  4 smong other applications this subject  4 sty support, embedded  4 se course is by external aspects.  4 ss. Students the scientific ew for each  4 ss. Students the scientific sty scientific aspects.
The course will intra suppliers (devs a NI-PSL The course introduces advance standard liance introduces in available 3D enging available 3D enging in available	Public Services Design  aduce students to specifics of UX, Service design and development for public sector. We will look into the design and development prince of the design and development prince of the state of	KZ ocess from the per or with client representation of the period of the	4 respective of entatives.  4 stching and Cassandra,  4 smong other applications this subject  4 sty support, embedded  4 se course is by external aspects.  4 ss. Students the scientific ew for each  4 ss. Students the scientific sty scientific aspects.

NI-SEP	World Economy and Business	Z,ZK	4
	resented in Czech. However, there is an English variant in the program Informatics (N1801 / 4793). The course introduces students oness. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about dif		
	g business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for	-	
Seminars help to	p improve on the knowledge in the form of discussions based on individual readings. It is advised to take bachelor level of this course	BIE-SEP as a pre	requisite.
NI-SZ1	Knowledge Engineering Seminar Master I	Z	4
	r you will present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top resea Il learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machir		
taditionally, you wil	and summer schools, as well as FIT's own Summer Research Program (VyLet).	ne rearring and 7th	onicicnocs
NI-SZ2	Knowledge Engineering Seminar Master II	Z	4
	r you will present a research paper from a top institute / research group to your peers. You will learn what is being cooked in top research		
Additionally, you wil	ll learn how to properly present and read scientific papers. The work in the seminar will prepare you to attend (and profit from) top machin and summer schools, as well as FIT's own Summer Research Program (VyLet).	ne learning and Al (	conterences
NI-TKA	Category Theory	Z,ZK	4
NI-TNN	Theory of Neural Networks	Z,ZK	5
	study neural networks from the point of view of the theory of function approximation and from the point of view of probability theory. At		-
	ial neural Networks, such as neurons and connections between them, types of neurons from the point of view of signal transmission, , network training, and the role of time in neural networks. In connection with network topology, we get acquainted with its transforma		
	n with somatic and synaptic mappings, with their composition into mappings computed by the Network, Finally in connection with trai		
	ining and to the fact that training is actually a specific optimization task, recalling the most typical objective functions and the most im		
	Il network training. We will see the meaninig of all these concepts in the context of common kinds of forward neural networks. Within the		
	ks, we first notice the connection of neural networks to expressing functions of many variables using functions of fewer variables (Ko ds, we will see how the universal approximation capacity of neural networks can be mathematically formalized as the sets of mappings	•	
•	portant Banach spaces of functions, in particular in the spaces of continuous functions, spaces of functions integrable with respect to	· · · · ·	
	inuous derivatives, and Sobolev spaces. Within the topic probabilistic approach, we first get acquainted with training based on expec	•	
• •	id with probabilistic assumptions about training data with which those two kinds of neural networks can be employed. We will see how all expectancy of network outputs conditioned by its inputs using the expectancy based learning. We recall the strong and the weak la		
	n analogy of the strong law of large numbers for neural networks and with the assumptions for its validity. Finally, we recall the centra	•	•
with its analogy	for neural networks, with the assumptions for its validity and with the hypothesis tests based on it. We will see how those tests can be topology of the network.	e employed to sear	ch for the
NI-TS1	Theoretical Seminar Master I	Z	4
	r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic		
are treated individu	ally and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.	work with scientific	papers and
NI-TS2	Theoretical Seminar Master II	Z	4
	r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic	1 1	=
are treated individu	ally and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a	work with scientific	papers and
NII TOO	other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.	Z	4
NI-TS3 Theoretical semina	Theoretical Seminar Master III r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic	. – .	-
	ally and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a		
	other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.		
NI-TS4	Theoretical Seminar Master IV r is intended for students which want to come in deeper contact with contemporary theoretical computer science. It is mostly a classic	Z Z	4 ho students
	ially and concern themselves with interesting topics from the latest research in the area. Therefore, an integral part of the course is a		
	other scholarly literature. The capacity is limited by the the potentials of the teachers of the seminar.		
NI-TVR	Virtual Reality Technology	Z,ZK	3
	troduced to the basic concepts of virtual reality. Techniques for displaying virtual worlds (CAVE, HMD,) and the possibilities of cont cking, eye tracking) will be discussed. Furthermore, the concepts of mixed and augmented reality will be introduced. Finally, ways of	-	
traoiting, mana tra	reality will be presented.	doing virtual and a	agmontoa
NI-VGA	Video Games Architecture	Z,ZK	5
	s a wide range of topics, procedures and methodologies related to the development of computer games - from a technical point of vie		_
	of view. In the lectures, students will be guided through the history of development, the structure of game engines, component and fu s, physics, graphics, artificial intelligence and multiplayer. The exercises will then cover selected technological topics in greater detail, in		
<b>5</b>	some game mechanics, in the form of practical demonstrations.	g,	
NI-VOL	Elections	Z,ZK	5
NII V/DD	We will cover the basics of (committee) elections and, in general, opinion aggregation.		
NI-VPR	Research Project Student obtains the credits for published scientific outputs. The details are at https://courses.fit.cvut.cz/NI-VPR/en.	Z	5
NI-VYC	Computability	Z,ZK	4
	Classical theory of recursive functions and effective computability.	, -,	-
NI-ZS10	Master internship abroad for 10 credits	Z	10
	once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institu the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and ex		-
	the vice-dearnor study analis assesses the professional content. The student must provide evidence of the professional content and ex MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 week		
	on. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects	•	-
NII 7066	academic year's dead-line.		
NI-ZS20	Master internship abroad for 20 credits once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institu	Z	20 ernshin the
	once within his / her master's degree have a foreign internship at a foreign university of other foreign scientific and/or research institute the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and expensional content in the student must provide evidence of the professional content and expensional content in the student must be sufficient to the professional content and expensional content in the student must be sufficient to the professional content and expensional content in the student must be sufficient to the professional content and expensional content in the student must be sufficient to the professional content and expensional content in the student must be sufficient to the professional content and expensional content in the student must be sufficient to the s		-
	MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 week		

a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line. 30 NI-7S30 7 Master internship abroad for 30 credits The course is prezented in chzech language. Each student can once within his / her master's degree have a foreign internship at a foreign university or other foreign scientific and/or research institution. Before the internship the Dean of the FIT, or the vice-dean for study affairs assesses the professional content. The student must provide evidence of the professional content and extent of the internship. Auxiliary courses MI-ZS10, MI-ZS20, MI-ZS30 are used used for the evidence and evaluation of the internship in IS KOS. Every 10 credits correspond to 4 weeks of full-time employment with a foreign institution. The maximum number of credits a student can earn for one internship is 30 credits. This amount can be divided into two subjects if the internship exceeds the academic year's dead-line. NIE-BLO Blockchain Students will understand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platforms. They will be able to design, code and deploy a secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places an increased emphasis on the relationship between blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the students for implementing or supervising implementation of blockchain-based solutions in both academia and business. NIE-PDL Practical Deep Learning ΚZ 5 This course is designed to provide students with a comprehensive understanding of Deep Learning using PyTorch, a popular open-source machine learning framework. Throughout the course, students will develop practical skills in building and training deep neural networks, using PyTorch to solve real-world problems in fields such as computer vision and natural language processing. NIE-PML Personalized Machine Learning Z.ZK 5 Personalized machine learning (PML) is a sub-field of machine learning that aims to create models and predictions based on the unique characteristics and behaviors of individual entities. While PML is commonly used in applications such as recommender systems, which recommend items to users based on their personal interests, its principles can be applied to a wide range of other fields, including education, medicine, and chemical engineering. In this course, we will explore the latest PML methods from theoretical, algorithmic, and practical perspectives. Specifically, we will focus on cutting-edge models that are of interest to both the research and commercial communities. PI-SCN Seminars on Digital Design This subject deals with problems of realization and implementation of digital circuits - both combinational and sequential. Basic means of description of digital circuits and basic logic synthesis and optimization algorithms are described. Basics of EDA (Electronic Design Automation) systems are given, together with combinatorial problems emerging in EDA. **ONI-AVM** Adiabatic computing and variational methods The course introduces adiabatic computing and variational quantum algorithms (VQA). We start with a broad introduction to variational methods in physical chemistry (e.g., for calculating ground state of small molecules) and a recapitulation of advances in theoretical computer science (computational complexity and problems such as MAXCUT). We will present the EQA Conjecture and the unique games conjecture. We will present the adiabatic theorem and quantum speedup by quantum annealing (QA). We will build up an understanding of variational quantum algorithms by introducing and analysing, in turn, Variational quantum eigensolver (VQE), Quantum Approximate Optimization Algorithm (QAOA), and their Warm-started variants. As applications, we will highlight variational solvers for systems of linear equations and variational solvers for Markowitz portfolio management, with some discussion of the challenges in benchmarking of VQA. QNI-CPX Complexity Theory Z,ZK 6 Students will learn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the theory concerning practical (in)tractability of difficult problems. Diploma Project Independent work of the student under the guidance of the thesis supervisor. Teaching is based on individual consultations with the thesis supervisor or other consultants. The scope of teaching 30 ECTS (i.e. about 900 hours) includes consultations, preparation of theoretical and practical parts of the thesis, writing, preparation for defence and defence of the thesis before the commission. The course supervisor guarantees the quality of the Masters thesis assignment and its compliance with the graduate profile. QNI-KKP Cryptology and Quantum Computing Z,ZK The course covers methods and algorithms of cryptology and their relation to quantum computing. In the first introductory lectures, students will be introduced to the basic principles and algorithms of cryptography. Following these topics, students will be introduced to basic cryptanalytic methods. Then some cryptanalytic algorithms running on quantum computers will be presented. In this context, the problem of security of related cryptographic schemes will be discussed. The next lectures will be devoted to post-quantum algorithms. The last lectures deal with cryptosystems using quantum phenomena. QNI-KOS Quantum Optical Communications and Networks The course focuses on the basic principles and technologies for building and using quantum networks. Students will learn about the key components of quantum networks, including quantum repeaters, routers and switches, and their role in creating a scalable quantum Internet. Emphasis will be placed on quantum cryptography systems. Students will also learn the fundamentals of optics, optical networks, and classical cryptography as they relate to quantum key distribution (QKD) and quantum networks. The course will cover types and architectures of QKD systems (including practical implementation of quantum protocols) according to international standards, key generation and distribution in these systems, and integration of QKD with classical communication systems. Students will also have the opportunity to explore satellite and FSO QKD systems and integrated quantum photonics and electronics. QNI-LOM Linear Optimization and Methods Z,ZK Students learn the applications of optimization methods in computer science, economics, and industry. They are aware of practical importance of linear and integer programming. They are able to work with optimization software and are familiar with languages used in programming of that software. They get skills in formalization of optimization problems in computer science (such as scheduling of tasks to processors, analysis of network flows), distribution and allocation of resources (transportation problems, travelling salesman problems, etc.), issues from economics, and modelling of conflicts via the game theory. They get an overview of computational complexity of optimization problems. They get orientation in algorithms in linear programming. QNI-MPR Master Project 1. At the beginning of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial tasks that should be carried out during the semester. If the requirements they agreed upon are met, the supervisor awards the student an assessment for the course MI-MPR at the end of the semester. 2. The external supervisor enters the information on granting the credit using the form "Granting credit from the external supervisor of the final thesis" (http://fit.cvut.cz/student/studijni/formulare). The completed and signed form must be delivered in person or by email to the SZZ coordinator, who will arrange for the credit to be granted. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the upcoming semester should aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester. ONI-MOI Mathematics for Quantum Informatics 7.7K 6 Linear algebra on finite dimensional spaces with scalar product, Hilbert spaces, Dirac's bra-ket formalism, normal, Hermitian and unitary operators, operator spectrum, orthonormalization, diagonalization, matrix exponential, tensor product of vector spaces and operators. Discrete Fourier transform and fast Fourier transform. QNI-NMK Numerical methods for quantum computation The course is devoted to numerical solution of boundary-value problems and intial-boundary-value problems for ordinary and partial differential equations. It explains finite-difference, finite-element and finite-volume methods for elliptic, parabolic and hyperbolic partial differential equations. Students are introduced to the recent advances in methods solving the mentioned problems.

QNI-OPM	Optical measurements	Z,ZK	6		
	urse is to acquaint students with optical measurement methods from the detection of microparticles, non-regulation and surface breaters it is not possible to use standard electronic sensors, or in places with ingressed risk of explanion and in benefits by liders used in intelligences.				
•	re it is not possible to use standard electronic sensors, or in places with increased risk of explosion and in hospitals, lidars used in intell ensing (remote sensing) of the Earth, atmosphere and space. The inclusion of these measurement methods requires in particular an u				
to macroscopic do	mechanisms on which they are based, as well as knowledge of measurement procedures and specifics in data processing and reco	-	io priyologi		
QNI-OQC	Optical quantum computing	Z,ZK	5		
	the basic theoretical methods and concepts for optical quantum computing, complemented by on hands-on exercise and applications				
libraries, Strawberry Fields and Piquasso. Theoretical concepts include measurement-based quantum computation, Gaussian Boson Sampling, and quantum supremacy. Applications					
	on current and near-term hardware include recent generative and discriminative machine-learning algorithms, as well as molecular vi				
QNI-OVV	Optimization for Scientific Computing course is an explanation of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimization, convex optimization, stochastic optimization, optimization, optimization, convex optimization, stochastic optimization, optimization, optimization, optimization of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimization of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimization of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimization of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization, optimization of numerical methods for solving nonlinear optimization, convex optimization, stochastic optimization of numerical methods for solving nonlinear optimization.	Z,ZK	5		
	ic and evolutionary programming, machine learning, deep neural networks. Students are also introduced to modern trends in solving		0113 101 QO,		
QNI-PJK	Programming languages for quantum computing	Z,ZK	5		
	odels for quantum computing: quantum Turing machine, QRAM, lambda calculus with qubits. Higher programming languages for quar	tum computation:			
	(Silq), functional languages (QML, Quipper). ). In the seminars the student will learn the basics of programming in the higher program	nming language Si			
QNI-PNM	Parallelization of numerical methods	Z,ZK	5		
The content of the course is an explanation of numerical methods for solving mathematical models with a focus on their parallelization and the use of these methods in QC. Students					
QNI-PON	are also introduced to modern trends in the field of solving these problems.  Selected Topics in Optimization and Numerical mathematics	Z,ZK	5		
	introduced to special optimization problems that arise in the field of machine learning and artificial intelligence and will extend the bas				
optimization acquired in previous studies. They will also learn about the details of implementing solutions to these problems on a computer and related mathematical concepts, especially					
	from numerical linear algebra.	•			
QNI-PPS	Programming of parallel systems	Z,ZK	6		
Nowadays, multi-co	ore processors and GPU accelerators have become common components of computing clusters and high-performance computing sys	tems, so knowledg	e and skills		
•	programming are essential for every computer scientist. The aim of this course is to introduce students to the architectures and prog	· ·			
•	red memory, GPU accelerators, or with distributed memory. To effectively use these modern computing systems, it is essential to com	•			
	Students will gain knowledge of the relevant programming models, languages and environments. They will become familiar with fundathe limitations, efficiency, and scalability of parallel solutions to selected problems on high-performance computing systems. In additi				
be able to analyze	lectures, students will gain practical experience and skills in programming in OpenMP, CUDA and MPI environments.	on to the necessar	y triedry iri		
QNI-QC1	Quantum Computation 1	Z,ZK	6		
	ces the student to basic principles of quantum computation and shows the difference between classical and quantum mechanics. Quantum	,	_		
circuits, which will b	e demonstrated in the Qiskit SDK. The course will gradually introduce the student to such concepts the state of a quantum system and its	s visualization, mea	surements,		
basic gates and the	ir composition, and the so-called entanglement. The student will be introduced to the BB84 and E91 protocols as demonstrations of the	properties of quar	ntum states.		
The course will also	o cover quantum teleportation, quantum oracle queries, the Deutsch-Jozsa algorithm, the quantum Fourier transform, the phase estin	nation algorithm, a	nd the Shor		
QNI-QC2	algorithm.	Z,ZK	6		
	Quantum Computing 2 uting 2 focuses on advanced quantum algorithms and their implementations: the Grover algorithm and its applications, quantum algor		-		
Quantum compe	problems, HHL for solving systems of linear equations. In the course we also introduce students to variational methods and error or	-	. aigobia		
QNI-QEC	Quantum error correction	Z,ZK	5		
In this course, we v	will build a theory for the construction of quantum error-correcting codes. In the introductory part, necessary chapters from the classic	al theory will be su	ımmarized,		
atop of which we then present the quantum analogy. We will show how coherently stored quantum information can be made robust to loss and noise. We conclude the course by					
arriving at the pri	nciple of fault tolerance, based on which quantum computers are able to continuously correct errors arising at runtime and thus achie	eve correct results	even with		
ONII ONII	erroneous bits, gates or measurements.	7.71/			
QNI-QML	Quantum machine learning urse is to introduce students to quantum machine learning. Students will first learn theoretically and practically about the quantum rep	Z,ZK	5		
	ore kernel methods, the quantum SVM model, and the use of quantum variational methods in supervised learning scenarios. The cour				
	d quantum generative adversarial models in unsupervised learning scenarios. The primary focus of the course is quantum algorithms fo				
	will use the pandas and qiskit libraries for Python to work with data and models.				
QNI-QOM	Quantum Optics, Metrology, Sensing and Imaging	Z,ZK	5		
=	an introduction to the quantum theory of light and related fundamental principles with an emphasis on practical aspects. They acquire th		-		
	development of specifically quantum mechanical approaches to metrology and imaging in quantum computing and communications				
=	processes with photons (absorption, emission, stimulated emission), interference, entanglement, non-classical phenomena with phoaberrations and dispersion. The various techniques are explained theoretically and also using experiments that demonstrate these pri				
QNI-TIN	Information Theory		6		
	s on the mathematical description of a random message source, its coding and transmission of the source through a noisy channel. The	Z,ZK   e coding problem is			
	e relation of the mean length of the optimal code with the entropy and entropy rate of the random source is emphasized. In the case	- ·			
on the set of typical	sequences and its appropriate coding by self-correcting codes. The course includes a reminder of necessary concepts such as condition	al distributions, god	dness-of-fit		
	and independence tests, and an introduction to random chains.				
QNI-UKT	Introduction to Quantum Theory	Z,ZK	6		
interpretation of quantum theory are explained using simple models mainly from finite-dimensional quantum mechanics. Emphasis is placed on further applications of quantum theory					
to information processing and communication. Possible physical realizations of a qubit, description of multipartite systems, quantum entanglement and its applications are discussed. The course concludes with a description of continuous quantum systems in infinite-dimensional Hilbert spaces, in particular the linear harmonic oscillator as a description of the mode					
o oodigo oonolut	of a quantized electromagnetic field.	. ao a accomption (	and mode		
QNI-VOT	Fiber Optic Technology	Z,ZK	6		
	se is to introduce the mechanisms of optical wave propagation in optical fibres and fibre components. Furthermore, the knowledge of op		-		
and measurement r	methods for the characterisation of optical fibres. The content includes both methodologies for measuring design and transmission parameters.	eters for optical com	nmunication		
systems such as	numerical aperture, attenuation, dispersion, as well as measurements of basic characteristics of active and passive elements of option	al communication	systems -		
	connectors, couplers, coupling elements, refractive indices.				

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