## Study plan

# Name of study plan: Master specialization Computer Systems and Networks, in English, 2021

Faculty/Institute/Others:

Department:

Branch of study guaranteed by the department: Welcome page

Garantor of the study branch: Program of study: Informatics

Type of study: Follow-up master full-time

Required credits: 98

Elective courses credits: 22 Sum of credits in the plan: 120

Note on the plan: The study plan is intended for those students who have been accepted to study since the

academic year 2021/2022. . Guarantor: prof. Ing. Pavel Tvrdík, CSc., email: pavel.tvrdik@fit.cvut.cz

Name of the block: Compulsory courses in the program

Minimal number of credits of the block: 63

The role of the block: PP

Code of the group: NIE-PP.21

Name of the group: Compulsory Courses of Master Study Program, Version 2021

Requirement credits in the group: In this group you have to gain 63 credits

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

Credits in the group: 63 Note on the group:

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
NIE-KOP	Combinatorial Optimization Petr Fišer, Jan Schmidt Petr Fišer Petr Fišer (Gar.)	Z,ZK	6	3P+1C	Z	PP
NIE-DIP	<b>Diploma Project</b> Zden k Muziká <b>Zden k Muziká</b> Zden k Muziká (Gar.)	Z	30	270ZP	L,Z	PP
NIE-MPR	Master Project Zden k Muziká Zden k Muziká (Gar.)	Z	7		Z,L	PP
NIE-MPI	Mathematics for Informatics Francesco Dolce Št pán Starosta Št pán Starosta (Gar.)	Z,ZK	7	3P+2C	Z	PP
NIE-PDP	Parallel and Distributed Programming Pavel Tvrdík Pavel Tvrdík (Gar.)	Z,ZK	6	2P+2C	L	PP
NIE-VSM	Selected statistical Methods Petr Novák Pavel Hrabák Pavel Hrabák (Gar.)	Z,ZK	7	4P+2C	L	PP

## Characteristics of the courses of this group of Study Plan: Code=NIE-PP.21 Name=Compulsory Courses of Master Study Program, Version 2021

NIE-KOP	Combinatorial Optimization	Z,ZK	6
The students will gain k	nowledge and understanding necessary deployment of combinatorial heuristics at a professional level. They will be able not	only to select and	implement but
also to apply and evalua	ate heuristics for practical problems.		
NIE-DIP	Diploma Project	Z	30

NIE-MPR | Master Project | Z | 7 |

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.

NIE-MPI   Mathematics for Informati	CS
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Z,ZK 7

The course focuses on selected topics from general algebra with emphasis on finite structures used in computer science. It includes topics from multi-variate analysis, smooth optimization, and multi-variate integration. The third large topic is computer arithmetics and number representation in a computer along with error manipulation. The last topic includes selected numerical algorithm and their stability analysis. The topics are completed with the demonstration of applications in computer science. The course focuses on clear presentation and argumentation.

NIE-PDP Parallel and Distributed Programming

Z,ZK

6

21st century in computer architectures is primarily influenced by the shift of the Moore's law into parallelization of CPUs at the level of computing cores. Parallel computing systems are becoming a ubiquitous commodity and parallel programming becomes the basic paradigm of development of efficient applications for these platforms. Students get acquainted with architectures of parallel and distributed computing systems, their models, theory of interconnection networks and collective communication operations, and languages and environments for parallel programming of shared and distributed memory computers. They get acquianted with fundamental parallel algorithms and on selected problems, they will learn the techniques of design of efficient and scalable parallel algorithms and methods of performance evaluation of their implementations. The course includes a semester project of practical programming in OpenMP and MPI for solving a particular nontrivial problem.

NIE-VSM

Selected statistical Methods

Z,ZK

Z.ZK

5

7

Summary of probability theory; Multivariate normal distribution; Entropy and its application to coding; Statistical tests: T-tests, goodness of fit tests, independence test; Random processes - stacionarity; Markov chains and limiting properties; Queuing theory

Name of the block: Compulsory courses in the specialization

Distributed Systems and Computing

security events (i.e. incident handling and incident response).

Minimal number of credits of the block: 35

The role of the block: PS

Code of the group: NIE-PSS-PS.21

Name of the group: Compulsory Courses of Master Specialization Computer Systems and Networks, version

2021, in Czech

NIE-DSV

Requirement credits in the group: In this group you have to gain 35 credits

Requirement courses in the group: In this group you have to complete 7 courses

Credits in the group: 35

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
NIE-DSV	Distributed Systems and Computing Pavel Tvrdík, Peter Macejko Peter Macejko Pavel Tvrdík (Gar.)	Z,ZK	5	2P+1C	Z	PS
NIE-EPC	Effective C++ programming Daniel Langr Daniel Langr Daniel Langr (Gar.)	Z,ZK	5	2P+1C	Z	PS
NIE-GPU	GPU Architectures and Programming Ivan Šime ek Ivan Šime ek Ivan Šime ek (Gar.)	Z,ZK	5	2P+1C	L	PS
NIE-MTI	Modern Internet Technologies  Viktor erný, Alexandru Moucha Alexandru Moucha (Gar.)	Z,ZK	5	2P+1C	Z	PS
NIE-MCC	Multicore CPU Computing Daniel Langr, Ivan Šime ek Ivan Šime ek (Gar.)	Z,ZK	5	2P+1C	Z	PS
NIE-SIB	Network Security Tomáš Zahradnický, Ji í Dostál, Simona Forn sek, Gramoz Cubreli Simona Forn sek Ji í Dostál (Gar.)	Z,ZK	5	2P+1C	L	PS
NIE-VCC	Virtualization and Cloud Computing Tomáš Vondra, Jan Fesl Tomáš Vondra Tomáš Vondra (Gar.)	Z,ZK	5	2P+1C	L	PS

## Characteristics of the courses of this group of Study Plan: Code=NIE-PSS-PS.21 Name=Compulsory Courses of Master Specialization Computer Systems and Networks, version 2021, in Czech

Students are introduced	to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of compu	ting processes and	d communication
channels. They learn ba	isic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms th	at support high a	vailability of both
data and services, and	safety in case of failures.		
NIE-EPC	Effective C++ programming	Z,ZK	5
Students learn how to u	se the modern features of contemporary versions of the C++ programming language for software development. The course for	ocuses on prograi	mming effectivity
and efficiency in the for	m of writing maintainable and portable source code and creating correct programs with low memory and processor time requ	irements.	
NIE-GPU	GPU Architectures and Programming	Z,ZK	5
Students will gain know	edge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the	CUDA programm	ing environment,

Students will gain knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUDA programming environment, which is already a widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical computational structures, students will also learn optimization programming techniques and methods of programming multiprocessor GPU systems.

NIE-MTI | Modern Internet Technologies | Z,ZK | 5 | Students learn advanced networking technologies and protocols for both local area networks and wide area networks. They get acquainted with routing techniques and transfer technologies of modern internet, including multimedia data transfer, with various types of network virtualization, and with last-mile security.

NIE-MCC Multicore CPU Computing Z,ZK 5

Students will get acquainted in detail with hardware support and programming technologies for the creation of parallel multithreaded computations on multicore processors with shared and virtually shared memory, which are today the most common computing nodes of powerful computer systems. Students will gain knowledge of architecturally specific optimization techniques used to reduce the decrease in computing power due to the widening performance gap between the computational requirements of multi-core CPUs and memory interface throughput. On specific non-trivial multithreaded programs, students will also learn the basics of the art of creating these applications.

NIE-SIB Network Security

The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected

NIE-VCC Virtualization and Cloud Computing

Z,ZK

. . .

Students will gain knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and organizations. They will get acquainted with virtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficiently operate and optimize the performance parameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effective technology today for the management of complex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in the use of modern integration and development tools (Continuous integration and development).

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

The role of the block: V

Code of the group: NIE-PSS-VS.21

Name of the group: Elective Vocational Courses for Master Specialization Computer Systems and Networks

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

Credits in the group: 0 Note on the group:

	Name of the course / Name of the group of courses					
Code	(in case of groups of courses the list of codes of their members)	Completion	Credits	Scope	Semester	Role
HE KDV	Tutors, authors and guarantors (gar.)  Advanced Cryptology	7.71/		00.00	7	
NIE-KRY	Ji í Bu ek, Róbert Lórencz <b>Ji í Bu ek</b> Róbert Lórencz (Gar.)	Z,ZK	5	2P+2C	Z	V
NIE-PDB	Advanced Database Systems Martin Svoboda Martin Svoboda (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-PIS	Advanced Information Systems Petr Kroha, Petra Pavlí ková Petr Kroha (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-AIB	Algorithms of Information Security Martin Jure ek, Róbert Lórencz Martin Jure ek Róbert Lórencz (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-ADP	Architecture and Design patterns Ji í Borský Ji í Borský Filip K ikava (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-MVI	Computational Intelligence Methods  Miroslav epek, Pavel Kordík Pavel Kordík (Gar.)	Z,ZK	5	2P+1C	Z	٧
NIE-KOD	Data Compression Jan Holub Jan Holub (Gar.)	Z,ZK	5	2P+1C	L	٧
NIE-ADM	Data Mining Algorithms Rodrigo Augusto Da Silva Alves Rodrigo Augusto Da Silva Alves Pavel Kordík (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-SIM	Digital Circuit Simulation and Verification Martin Kohlík Martin Kohlík Martin Kohlík (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-EVY	Efficient Text Pattern Matching Jan Holub Jan Holub (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-EHW	Embedded Hardware Jan Schmidt Jan Schmidt (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-BVS	Embedded Security Ji í Bu ek, Martin Novotný Martin Novotný (Gar.)	Z,ZK	5	2P+2C	L	V
NIE-ESW	Embedded Software Hana Kubátová, Miroslav Skrbek Miroslav Skrbek Hana Kubátová (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-BKO	Error Control Codes Pavel Kubalík Pavel Kubalík (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-FME	Formal Methods and Specifications Stefan Ratschan Stefan Ratschan (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-GAK	Graph theory and combinatorics  Michal Opler Tomáš Valla Tomáš Valla (Gar.)	Z,ZK	5	2P+2C	L	V
NIE-HWB	Hardware Security Ji Bu ek Ji i Bu ek Ji i Bu ek (Gar.)	Z,ZK	5	2P+2C	L	V
NIE-MKY	Mathematics for Cryptology Martin Jure ek, Róbert Lórencz, Olha Jure ková Róbert Lórencz Róbert Lórencz (Gar.)	Z,ZK	5	3P+1C	L	V
NIE-AM1	Middleware Architectures 1 Tomáš Vitvar, Milan Doj inovski, Jaroslav Kucha Jaroslav Kucha Tomáš Vitvar (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-SIB	Network Security Tomáš Zahradnický, Ji í Dostál, Simona Forn sek, Gramoz Cubreli Simona Forn sek Ji í Dostál (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-NON	Nonlinear Continuous Optimization and Numerical Methods  Jaroslav Kruis Jaroslav Kruis (Gar.)	Z,ZK	5	2P+1C	Z,L	V
NIE-NSS	Normalized Software Systems Jan Verelst, Robert Pergl, Marek Suchánek Robert Pergl Robert Pergl (Gar.)	ZK	5	2P	L	V
NIE-SYP	Parsing and Compilers Jan Janoušek Jan Janoušek (Gar.)	Z,ZK	5	2P+1C	Z	V

NIE-REV	Reverse Engineering Josef Kokeš Josef Kokeš (Gar.)	Z,ZK	5	1P+2C	Z	V
NIE-SBF	System Security and Forensics Tomáš Zahradnický, Ji í Bu ek, Simona Forn sek, Marián Svetlík Simona Forn sek Simona Forn sek (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-TES	Systems Theory Tomáš Kolárik, Stefan Ratschan, Ji í Vysko il Stefan Ratschan Stefan Ratschan (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-TSP	Testing and Reliability Petr Fišer Petr Fišer (Gar.)	Z,ZK	5	2P+2C	Z	٧
NIE-NUR	User Interface Design Josef Pavlí ek Josef Pavlí ek (Gar.)	Z,ZK	5	2P+1C	Z	V

## Characteristics of the courses of this group of Study Plan: Code=NIE-PSS-VS.21 Name=Elective Vocational Courses for Master

**Specialization Computer Systems and Networks** NIE-SIB **Network Security** Z,ZK 5

The students will gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically about detection and defense. The course explains basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network traffic. The course focuses on explanation and practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general principals of handling detected security events (i.e. incident handling and incident response).

Advanced Cryptology NIE-KRY

Students will learn the essentials of cryptanalysis and the mathematical principles of constructing symmetric and asymmetric ciphers. They will know the mathematical principles of random number generators. They will have an overview of cryptanalysis methods, elliptic curve cryptography and quantum cryptography, which they can apply to the integration of their own systems or to the creation of their own software solutions.

NIF-PDB **Advanced Database Systems** 

Students orient themselves in problems of evaluation and optimization of SQL queries. The next part of the course deals with new concepts of database machines (so called NoSQL databases), with the related new data models (XML, graph databases, column databases) and languages for working with them (XQuery, XPath, CYPHER, Gremlin). The last part of the course deals with performance evaluation of database machines. This course is equivalent to the course MIE-PDB.

#### NIE-PIS Advanced Information Systems

Z.ZK

Students learn the notion of business process logic and its formalization, with business process roles, business rules, and data processing, with the notion of service oriented company, enterprise services and service solution of business logic. They get acquainted with these notions also for the other types of ISs. They learn about agility and adaptivity and using of artificial intelligence methods for implementation of these ideas in ISs. They understand modern object-oriented methodologies for modelling of business processes, business rules, processed data, and enterprise ISs. They will get the rules and technologies for successful implementation of IS.

### Algorithms of Information Security

Students will get acquainted with the algorithms of secure key generation and cryptographic error (not only biometric) data processing. Furthermore, students will learn the mathematical principles of cryptographic protocols (identification, authentication, and signature schemes). Another part of the course is dedicated to malware detection and the use of machine learning in detection systems. The last topic includes practical steganographic methods and attacks on steganographic systems.

### Architecture and Design patterns

The objective of this course is to provide students with both work knowledge about the underlying foundations of object-oriented design and analysis as well as with understanding of the challenges, issues, and tradeoffs of advanced software design. In the first part of the course, the students will refresh and deepen their knowledge of object-oriented programming and get familiar with the commonly used object-oriented design patterns that represent the best practices for solving common software design problems. In the second part the students will be introduced to the principles of software architecture design and analysis. This includes the classical architectural styles, component based systems, and some advanced software architectures used in large-scale distributed systems.

#### Computational Intelligence Methods NIE-MVI

Z,ZK

5

Students will understand the basic methods and techniques of computational intelligence, which are based on traditional artificial intelligence, are parallel in nature and are applicable to solving a wide range of problems. The subject is also devoted to modern neural networks and the ways in which they learn and neuroevolution. Students will learn how these methods work and how to apply them to problems related to data extraction, management, intelligence in games and optimisation, etc.

#### NIE-KOD **Data Compression**

Z,ZK

5

Students are introduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data compression methods being used in practice. The overview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In addition, students learn the fundamentals of lossy data compression methods used in image, audio, and video compression.

#### NIE-ADM **Data Mining Algorithms**

Z.ZK

The course focuses on algorithms used in the fields of machine learning and data mining. However, this is not an introductory course, and the students should know machine learning basics. The emphasis is put on advanced algorithms (e.g., gradient boosting) and non-basic kinds of machine learning tasks (e.g., recommendation systems) and models (e.g., kernel methods)

#### NIE-SIM Digital Circuit Simulation and Verification

Z,ZK

5

Aim of the course is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level Modeling) levels and with the properties of proper tools. The course covers today recent verification methods, too.

#### NIE-EVY Efficient Text Pattern Matching

Z,ZK

Students get knowledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access time and memory complexity. They will be able to use the knowledge in design of applications that utilize pattern matching.

#### NIE-EHW **Embedded Hardware**

The course brings basic laws that govern digital design and basic techniques to use them. It deals with both large and small scale systems. This is the base of advanced embedded systems, that profit from their specialized structure for effective computation and acceleration. Design of fast custom computing machines is discussed, including standardized means of internal communication, parallelism extraction and utilization in special structures and system architectures.

### **Embedded Security**

Students gain basic knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of cryptographic primitives in hardware and software (in embedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources for securing internal functions of computer systems.

#### **NIE-ESW Embedded Software**

Embedded software course acquainted students with the specifics of software development for embedded systems. The course covers the areas from the basic techniques of programming in C language and code optimizations, through typical areas as the reliable software development, embedded operating systems, signal processing, up to sophisticated techniques combined with artificial intelligence.

NIE-BKO **Error Control Codes** The course expands the basic knowledge of security codes used in current systems for error detection and correction. It provides the necessary mathematical theory and principles of linear, cyclic codes and codes for the correction of multiple errors, clusters of errors and whole syllables (bytes). Students will also learn how to implement these detections and corrections for different types of transmissions (parallel, serial) when storing data in memory and when transmitting over telecommunication channels Formal Methods and Specifications Students are able to describe semantics of software formally and to use sound reasoning for construction of correct software. They learn to use some software tools that allow to prove basic properties of software NIE-GAK Graph theory and combinatorics The goal of the class is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithms. The emphasis will be not only on undestanding the basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected topics from graph and hypergraph coloring, Ramsey theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory will be also applied in the fields of combinatorics on words, formal languages and bioinformatics. NIE-HWB Hardware Security The course provides the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards against abuse of the system using hardware means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students will gain knowledge about the cryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions of the computer. Z,ZK NIE-MKY Mathematics for Cryptology 5 Students will gain deeper knowledge of algebraic procedures solving the most important mathematical problems concerning the security of ciphers. In particular, the course focuses on the problem of solving a system of polynomial equations over a finite field, the problem of factorization of large numbers and the problem of discrete logarithm. The problem of factorization will also be solved on elliptic curves. Students will further become familiar with modern encryption systems based on lattices. NIE-AM1 Middleware Architectures 1 Z,ZK 5 Students will study new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information system architecture, web service architecture and aplication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous communications and high availability of applications. This course replaces the course MIE-MDW. NIE-NON Nonlinear Continuous Optimization and Numerical Methods Z.ZK Students will be introduced to nonlinear continuous optimization, principles of the most popular methods of optimization and applications of such methods to real-world problems. They will also learn the finite element method and the finite difference method used for solving ordinary and partial differential equations in engineering. They will learn to solve systems of linear algebraic equations that arise from discretization of the continuous problems by direct and iterative algorithms. They will also learn to implement these algorithms sequentially as well as in parallel. **NIE-NSS** Normalized Software Systems ZK Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures. NIE-SYP Parsing and Compilers Z.ZK 5 The module builds upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of various variants and applications of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing. Z,ZK Reverse Engineering Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction. Z,ZK NIF-SBF System Security and Forensics Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection). Z,ZK**NIE-TES** Systems Theory Today, humankind has the ability to develop systems of incredible complexity (e.g., trains, microprocessors, airplanes, nuclear power plants). However, the costs of managing this complexity and of ensuring the correct behavior of a given system have become critical. A key technique for mastering this complexity is the usage of models that describe only those aspects of the systems that are important for the task at hand, and automated tools for analyzing those models. This subject will present theory and algorithms that form the basis for **NIE-TSP** Testing and Reliability Students will gain knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to prepare a test set with the help of

the modeling and analysis of complex systems

the intuitive path sensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with built-in-self-test equipment. They will be able to compute, analyze, and control the reliability and availability of the designed circuits.

User Interface Design

Students will understand the theorical background of human-computer interaction and user interface (UI) design, will learn formal description of UIs, formal user models, the fundamental notions and procesures. They get acquainted with graphical, speech, and multimodal UIs. Thanks to the gained knowledge, the students will be able to design advanced UIs.

Code of the group: NIE-V.21

Name of the group: Purely elective master's courses

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

Credits in the group: 0 Note on the group:

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
NIE-BLO	Blockchain Josef Gattermayer, Róbert Lórencz, Jakub R ži ka, Marek Bielik Josef Gattermayer Róbert Lórencz (Gar.)	Z,ZK	5	1P+2C	Z	V
NIE-CPX	Complexity Theory Dušan Knop, Ond ej Suchý Dušan Knop Dušan Knop (Gar.)	Z,ZK	5	3P+1C	Z	V
NIE-VYC	Computability Jan Starý Jan Starý (Gar.)	Z,ZK	4	2P+2C	L	V
NIE-MVI	Computational Intelligence Methods  Miroslav epek, Pavel Kordík Pavel Kordík Pavel Kordík (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-ARI	Computer arithmetic Pavel Kubalík Pavel Kubalík (Gar.)	Z,ZK	4	2P+1C	Z,L	V
NIE-SCE1	Computer Engineering Seminar Master I Hana Kubátová Hana Kubátová Hana Kubátová (Gar.)	Z	4	2C	Z	V
NIE-SCE2	Computer Engineering Seminar Master II  Hana Kubátová Hana Kubátová Hana Kubátová (Gar.)	Z	4	2C	L	V
NI-DSW	Design Sprint Ond ej Brém, Michal Manda Michal Manda David Pešek (Gar.)	Z	2	30B	Z	V
NI-DID	Digital drawing  Denisa Nová ková, Eliška Novotná Denisa Nová ková Denisa Nová ková (Gar.)	Z	2	4C	Z,L	V
NIE-EVY	Efficient Text Pattern Matching  Jan Holub Jan Holub Jan Holub (Gar.)	Z,ZK	5	2P+1C	Z	V
NI-GLR	Games and reinforcement learning  Juan Pablo Maldonado Lopez	Z,ZK	4	2P+2C	L	V
NI-GRI	Grid Computing  André Sopczak, Petr Fiedler Pavel Tvrdík André Sopczak (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-HMI	History of Mathematics and Informatics  Alena Šolcová Alena Šolcová (Gar.)	Z,ZK	3	2P+1C	Z	V
NIE-DVG	Introduction to Discrete and Computational Geometry Maria Saumell Mendiola Maria Saumell Mendiola (Gar.)	Z,ZK	5	2P+1C	L	V
FITE-EHD	Introduction to European Economic History Tomáš Evan	Z,ZK	3	2P+1C	L	V
MIE-MZI	Mathematics for data science Št pán Starosta	Z,ZK	4	2P+1C	L	V
NIE-AM2	Middleware Architectures 2 Milan Doj inovski Milan Doj inovski (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-PAM	Parameterized Algorithms Ond ej Suchý Ond ej Suchý Ond ej Suchý (Gar.)	Z,ZK	4	2P+1C	L	V
NIE-SYP	Parsing and Compilers  Jan Janoušek <b>Jan Janoušek</b> Jan Janoušek (Gar.)	Z,ZK	5	2P+1C	Z	V
NIE-ROZ	Pattern Recognition Michal Haindl Michal Haindl (Gar.)	Z,ZK	5	2P+1C	Z	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-AML	Advanced machine learning  Zden k Buk, Miroslav epek, Petr Šimánek, Rodrigo Augusto Da Silva Alves, Vojt ch Rybá <b>Miroslav epek</b> Miroslav epek (Gar.)	Z,ZK	5	2P + 1C	L	V
NIE-PDL	Practical Deep Learning Martin Barus, Yauhen Babakhin Karel Klouda Karel Klouda (Gar.)	KZ	5	2P+1C	Z	V
NIE-VPR	Research Project Št pán Starosta Št pán Starosta (Gar.)	Z	5		Z,L	V
NIE-SWE	Semantic Web and Knowledge Graphs  Milan Doj inovski Milan Doj inovski (Gar.)	Z,ZK	5	2P+1C	Z	V
MI-SCE1	Computer Engineering Seminar Master I  Hana Kubátová	Z	4	2C	L,Z	V
NIE-HSC	Side-Channel Analysis in Hardware  Vojt ch Miškovský, Petr Socha Vojt ch Miškovský Vojt ch Miškovský (Gar.)	Z,ZK	4	2P+2C	Z	V
NIE-DDW	Web Data Mining Milan Doj inovski Milan Doj inovski (Gar.)	Z,ZK	5	2P+1C	L	V
NIE-BPS	Wireless Computer Networks Alexandru Moucha Alexandru Moucha (Gar.)	Z,ZK	4	2P+1C	L	V
NIE-SEP	World Economy and Business Tomáš Evan	Z,ZK	4	2P+1C	Z	V
FITE-SEP	World Economy and Business Tomáš Evan	Z,ZK	4	2P+2C	Z	V

Characteristics of the courses of this group of Study Plan: Code=NIE-V.21 Name=Purely elective master's courses

NIE-MVI Computational Intelligence Methods

Students will understand the basic methods and techniques of computational intelligence, which are based on traditional artificial intelligence, are parallel in nature and are applicable to solving a wide range of problems. The subject is also devoted to modern neural networks and the ways in which they learn and neuroevolution. Students will learn how these methods work and how to apply them to problems related to data extraction, management, intelligence in games and optimisation, etc.

NIE-EVY	Efficient Text Pattern Matching	Z,ZK	5
	of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both account and are efficient as a superior of the efficient and are ef	cess time and mer	mory complexity.
	the knowledge in design of applications that utilize pattern matching.		
NIE-SYP	Parsing and Compilers	Z,ZK	5
•	the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of	of various variants	and applications
	troduced to special applications of parsers, such as incremental and parallel parsing.	7 71/	
NIE-BLO	Blockchain	Z,ZK	5 a abla ta dasign
	l the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain plat re decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course place		_
	ckchains and information security. It is concluded with a defense of a research or applied semester project, which prepares		•
•	tion of blockchain-based solutions in both academia and business.		.p.oorum.g o.
NIE-CPX	Complexity Theory	Z,ZK	5
	t the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the	, , , , , , , , , , , , , , , , , , ,	
(in)tractability of difficult	problems.		
NIE-VYC	Computability	Z,ZK	4
Classical theory of recu	sive functions and effective computability.		
NIE-ARI	Computer arithmetic	Z,ZK	4
Students will learn vario	us data representations used in digital devices and will be able to design arithmetic operations implementation units.		
NIE-SCE1	Computer Engineering Seminar Master I	Z	4
The Seminar of Comput	er 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 individu	ally within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of t	the subject is worl	k with scientific
articles and other profes	sional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar tead	chers. The topics a	are new for each
semester.		,	
NIE-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		
• •	ally within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of t	•	
•	sional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar teach	chers. The topics a	are new for each
semester.		_	
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	ith research and i	finishing with
testing the prototypes (p		-	
NI-DID	Digital drawing	Z	2
	e students to the basic principals of digital drawing and graphical design. Students will gain understanding of composition, po r in their own design works. Students will also gain experience in drawing and painting with digital and analog tools. The cour	-	-
triev will bractically appr			
		=	e who wants to
practice or learn drawing	and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practice ga	ined knowledge.	
practice or learn drawing	g and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practice ga Games and reinforcement learning	ined knowledge.	4
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practice or learn drawing NI-GLR The field of reinforceme give you both theoretical NI-GRI Grid computing and gain NIE-HMI The course focuses on a for finding some relation NIE-DVG The course intends to in of this discipline, and to FITE-EHD The course introduces a of the key periods in his area of Roman Empire to does not cover detailed meetings will consist of MIE-MZI In this course, the stude include mainly: linear algorithms selected notions from provided include mainly: linear algorithms will learn new for microservices, distruent of microservices, distruent of the inputs and polynomially in the which is not possible in plethora of parameterize will also not miss out the NIE-ROZ The aim of the module is	grand painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practice ga Games and reinforcement learning It 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.  Grid Computing I knowledge about the world-wide network and computing infrastructure.  History of Mathematics and Informatics selected topics from calculus, general algebra, number theory, numerical mathematics and logic - useful for today computer is between computer science and mathematical methods. Some examples of applications of mathematics to computer science Introduction to Discrete and Computational Geometry troduce the students to the discipline of Discrete and Computational Geometry. The main goal of the course is to get familiar to eable to solve simple algorithmic problems with a geometric component.  Introduction to European Economic History selection of themes from the European economic history. It gives the students basic knowledge about forming of the global etory. As European countries have been dominant actors in this process if focuses predominantly on their roles in the econom of ragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial insteconomic history of particular European countries but rather the impact of trade and role of particular events, institutions and a mixture of lecture and discussion.  Mathematics for data science its are introduced to the domains of mathematics necessary for understanding the standard methods and algorithms used in the particular events, institutions, eigenvalues, diagonalization), continuous optimisation (optimisation with constraints, duality prin obability theory and statistics.  Middleware Architectures 2  I trends and technologies on the Web including theoretical foundations. They will gain an overview o	z,ZK gence. This course z,ZK gence. This course z,ZK science The topics ces will be showe z,ZK with the most fund z,ZK gence The topics ces will be showe z,ZK with the most fund z,ZK gence The topics concept through the concept of	4 e is intended to  5  3 s are selected d.  5 lamental notions  3 the description arge economic ered. The course history. Class  4 the studied topics ethods) and  5 and technologies  4 se problems armon property small) parameter ing of the input, ill present a er not exist. We

#### NIE-PML Personalized Machine Learning 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. NI-AML Advanced machine learning Z.ZK 5 The course introduces students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of recommendation systems, 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 discussed. NIE-PDL Practical Deep Learning 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-VPR Research Project 5 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. External Master these (MT) supervisor fills his/her assessment into the paper "Form to award assessment by an external Final theses (FT) supervisor" (for the courses BIE-BAP, MIE-MPR, MIE-DIP). Students, then, ensure that the assessment is registered into the information system (IS) by asking their internal FT opponent to award the assessment to the IS based on the confirmation of the external MT supervisor. In the case the FT opponent is external as well, the assessment will be registered to the IS by the head of the department responsible for the topic of the MT. 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. Semantic Web and Knowledge Graphs Z,ZK The students will learn the most recent concepts and technologies of the Semantic Web. The course will provide an overview of the Semantic Web technologies, methods and best practices for modelling, integration, publishing, querying and consumption of semantic data. The students will also gain skills in creation of knowledge graphs and their systematic quality assurance. MI-SCE1 Computer Engineering Seminar Master I The Seminar of Computer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to failures and attacks. Students are approached individually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the subject is work with scientific articles and other professional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar teachers. The topics are new for each semester. NIE-HSC Side-Channel Analysis in Hardware 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. NIF-DDW Z,ZK 5 Web Data Mining Students will learn latest methods and technologies for web data acquisition, analysis and utilization of the discovered knowledge. Students will gain an overview of Web mining techniques for Web crawling, Web structure analysis, Web usage analysis, Web content mining and information extraction. Students will also gain an overview of most recent developments in the field of social web and recommendation systems. NIE-BPS Wireless Computer Networks Z,ZK Students will learn about the modern technologies, protocols, and standards for wireless networks. They will understand the routing mechanisms in ad-hoc networks, multicast and broadcast mechanisms, and data flow control mechanisms. They will also learn about principles of communication in sensor networks. They get knowledge of security mechanisms for wireless networks and get skills of configuration of wireless network elements and simulation of wireless networks using suitable tools. NIE-SEP World Economy and Business Z,ZK The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to 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 prerequisite. FITE-SEP World Economy and Business Z,ZK 4 The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy.

The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to 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 prerequisite.

## List of courses of this pass:

Code	Name of the course	Completion	Credits
FITE-EHD	Introduction to European Economic History	Z,ZK	3
The course intr	nduces a selection of themes from the European economic history. It gives the student basic knowledge about forming of the global eco	nomy through the	description
of the key perio	ds 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 I	mpire to fragmentation of the Middle Ages, from destruction of WWII to the current affairs, the development of modern financial instituti	ons 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 c	rganizations in his	tory. Class

meetings will consist of a mixture of lecture and discussion.

FITE-SEP World Economy and Business Z,ZK 4

The course introduces students of technical university to the international business. It does that predominantly by comparing individual countries and key regions of world economy. Students get to know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedom, corruption and economic development, which are needed for the right investment decision. Seminars help to 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 prerequisite.

MI-SCE1	Computer Engineering Seminar Master I	Z	4
The Seminar of Co	mputer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to	o failures and attack	s. Students
are approached in	dividually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the	subject is work wit	th scientific
articles and other	professional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar teacher	rs. The topics are n	ew for each
	semester.		
MIE-MZI	Mathematics for data science	Z,ZK	4
	students are introduced to the domains of mathematics necessary for understanding the standard methods and algorithms used in date		-
	inear algebra (matrix factorisations, eigenvalues, diagonalization), continuous optimisation (optimisation with constraints, duality princ		· ·
include mainly.		ipie, gradient metri	ious) ariu
	selected notions from probability theory and statistics.		
NI-AML	Advanced machine learning	Z,ZK	5
The course introdu	ces students to selected advanced topics of machine learning and artificial intelligence. The topics present techniques in the field of rec	commendation syst	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	the methods discus	ssed.
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		
	properties of the basic principals of algebra and many arise graphical design. Stadenic minigram and relational minigram and principal and analog tools. The course		-
		-	
	r learn drawing and painting. The course is organized as a thematic practices covering parts of theory and practical exercise to practic		
NI-DSW	Design Sprint	Z	2
Students will work	on projects using the Design Sprint method, developed by Google. THanks to this method the teams are able to go from idea to valida	ted prototype in 5 d	lays. During
the course the st	udents will get familiar with the method as participants. Through practical challenges they will try the whole 5 day process starting wit	h research and finis	shing with
	testing the prototypes (plus final presentation).		
NI-GLR	Games and reinforcement learning	Z,ZK	4
	reement learning is very hot recently, because of advances in deep learning, recurrent neural networks and general artificial intelligen	1	-
THE HEIGHT OF TORRIES	give you both theoretical and practical background so you can participate in related research activities. Presented in English		intoriada to
NII ODI			
NI-GRI	Grid Computing	Z,ZK	5
	Grid computing and gain knowledge about the world-wide network and computing infrastructure.		
NIE-ADM	Data Mining Algorithms	Z,ZK	5
	s on algorithms used in the fields of machine learning and data mining. However, this is not an introductory course, and the students		ine learning
	sis is put on advanced algorithms (e.g., gradient boosting) and non-basic kinds of machine learning tasks (e.g., recommendation syst		_
Daoison mio omprio	methods).	ionio, ana modelo (	(0.9.,
NIE ADD		7.71/	_
NIE-ADP	Architecture and Design patterns	Z,ZK	5
=	is course is to provide students with both work knowledge about the underlying foundations of object-oriented design and analysis as		_
-	ues, and tradeoffs of advanced software design. In the first part of the course, the students will refresh and deepen their knowledge o		
and get familiar wit	h the commonly used object-oriented design patterns that represent the best practices for solving common software design problems. I	n the second part t	he students
will be introduced to	o the principles of software architecture design and analysis. This includes the classical architectural styles, component based systems	, and some advanc	ed software
	architectures used in large-scale distributed systems.		
NIE-AIB	Algorithms of Information Security	Z,ZK	5
	equainted with the algorithms of secure key generation and cryptographic error (not only biometric) data processing. Furthermore, stude	1 ' 1	_
-	otographic protocols (identification, authentication, and signature schemes). Another part of the course is dedicated to malware detec		
principles of cry			macmine
	learning in detection systems. The last topic includes practical steganographic methods and attacks on steganographic syste		
NIE-AM1	Middleware Architectures 1	Z,ZK	5
Students will stu-	dy new trends, concepts, and technologies in the area of service-oriented architectures. The will gain an overview of information syste	em architecture, we	eb service
architecture and ap	lication servers. The will also study principles and technologies for middleware focused on application integrations, asynchronous comm	nunications and high	h availability
	of applications. This course replaces the course MIE-MDW.		
NIE-AM2	Middleware Architectures 2	Z,ZK	5
	new trends and technologies on the Web including theoretical foundations. They will gain an overview of Web application architecture		
Otadonio wiii icam	for microservices, distrubuted cache and databases, smart contracts, realtime communication and web security.	25, correcpts and to	ciliologics
NIE-ARI	Computer arithmetic	Z,ZK	4
	Students will learn various data representations used in digital devices and will be able to design arithmetic operations implementa	tion units.	
NIE-BKO	Error Control Codes	Z,ZK	5
The course expand	sthe basic knowledge of security codes used in current systems for error detection and correction. It provides the necessary mathen		orinciples of
	des and codes for the correction of multiple errors, clusters of errors and whole syllables (bytes). Students will also learn how to imple		•
	rrections for different types of transmissions (parallel, serial) when storing data in memory and when transmitting over telecommunica		
NIE-BLO	Blockchain	Z,ZK	5
	stand the foundations of blockchain technology, smart contract programming, and gain an overview of most notable blockchain platfor		
code and deploy a	secure decentralized application, and assess whether integration of a blockchain is suitable for a given problem. The course places a	an increased emph	asis on the
relationship betwe	een blockchains and information security. It is concluded with a defense of a research or applied semester project, which prepares the	students for imple	menting or
	supervising implementation of blockchain-based solutions in both academia and business.		
NIE-BPS	Wireless Computer Networks	Z,ZK	4
	n about the modern technologies, protocols, and standards for wireless networks. They will understand the routing mechanisms in ad		
	nisms, and data flow control mechanisms. They will also learn about principles of communication in sensor networks. They get knowle		
Dioducast HIECHA		-	0011011101110
NIE BY 10	for wireless networks and get skills of configuration of wireless network elements and simulation of wireless networks using suitable		
NIE-BVS	Embedded Security	Z,ZK	5
_	c knowledge in selected topics of cryptography and cryptanalysis. The course focuses particularly on efficient implementations of crypto		
and software (in en	nbedded systems). Students gain a good overview of functionality of (hardware) cryptographic accelerators, smart cards, and resources	s for securing intern	al functions
	of computer systems.		
NIE-CPX	Complexity Theory	Z,ZK	5
	rn about the fundamental classes of problems in the complexity theory and different models of algoritms and about implications of the		
	(in)tractability of difficult problems.	, 5555111119	, ,
NIE DOW		7 71/	
NIE-DDW	Web Data Mining	Z,ZK	5
	arn latest methods and technologies for web data acquisition, analysis and utilization of the discovered knowledge. Students will gain		_
techniques for Web	crawling, Web structure analysis, Web usage analysis, Web content mining and information extraction. Students will also gain an overvie	w of most recent de	evelopments
	in the field of social web and recommendation systems.		

	Diploma Project	Z	30
NIE-DSV	Distributed Systems and Computing	Z,ZK	5
Students are introd	duced to methods for coordination of processes in distributed environment characterised by nondeterministic time responses of computing		mmunicatio
channels. They lea	arn basic algorithms that assure correctness of computations realized by a group of loosely coupled processes and mechanisms that si data and services, and safety in case of failures.	upport high availa	ability of bot
NIE-DVG	Introduction to Discrete and Computational Geometry s to introduce the students to the discipline of Discrete and Computational Geometry. The main goal of the course is to get familiar with	Z,ZK	5
rne course intend	of this discipline, and to be able to solve simple algorithmic problems with a geometric component.	the most fundame	ental notion
NIE-EHW	Embedded Hardware	Z,ZK	5
The course bring	s basic laws that govern digital design and basic techniques to use them. It deals with both large and small scale systems. This is the	pase of advanced	embedded
systems, that prof	it from their specialized structure for effective computation and acceleration. Design of fast custom computing machines is discussed, i of internal communication, parallelism extraction and utilization in special structures and system architectures.	ncluding standard	dized mean
NIE-EPC	Effective C++ programming	Z,ZK	5
_	w to use the modern features of contemporary versions of the C++ programming language for software development. The course focus	•	_
and e	fficiency in the form of writing maintainable and portable source code and creating correct programs with low memory and processor ti	me requirements.	
NIE-ESW	Embedded Software	Z,ZK	5
	re course acquainted students with the specifics of software development for embedded systems. The course covers the areas from the bar	sic techniques of p	orogrammir
in C language ar	nd code optimizations, through typical areas as the reliable software development, embedded operating systems, signal processing, up	to sophisticated	techniques
	combined with artificial intelligence.		
NIE-EVY	Efficient Text Pattern Matching	Z,ZK	5
Students get know	reledge of efficient algorithms for text pattern matching. They learn to use so called succinct data structures that are efficient in both access		y complexi
	They will be able to use the knowledge in design of applications that utilize pattern matching.		
NIE-FME	Formal Methods and Specifications	Z,ZK	5
	to describe semantics of software formally and to use sound reasoning for construction of correct software. They learn to use some sof	•	_
	basic properties of software.		•
NIE-GAK	Graph theory and combinatorics	Z,ZK	5
	ass is to introduce the most important topics in graph theory, combinatorics, combinatorial structures, discrete models and algorithms.	The emphasis wil	be not on
-	he basic principles but also on applications in problem solving and algorithm design. The topics include: generating functions, selected topic	•	
_	theory, introduction to probabilistic method, properties of various special classes of graphs and combinatorial structures. The theory w		
J. ,	of combinatorics on words, formal languages and bioinformatics.		
NIE-GPU	GPU Architectures and Programming	Z,ZK	5
	knowledge of the internal architecture of modern massively parallel GPU processors. They will learn to program them mainly in the CUE	•	_
	widespread programming technology of GPU processors. As an integral part of the effective computational use of these hierarchical com		
, ,	will also learn optimization programming techniques and methods of programming multiprocessor GPU systems.		,
NIE-HMI	History of Mathematics and Informatics	Z.ZK	3
	ses on selected topics from calculus, general algebra, number theory, numerical mathematics and logic - useful for today computer sciences of selected topics from calculus, general algebra, number theory, numerical mathematics and logic - useful for today computer sciences.	,	_
for finding	some relations between computer science and mathematical methods. Some examples of applications of mathematics to computer sc	-	
	some relations between computer science and mathematical methods. Some examples of applications of mathematics to computer sc	iences will be sho	wed.
NIE-HSC	Side-Channel Analysis in Hardware	iences will be sho	owed.
NIE-HSC This course is d	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack	iences will be sho Z,ZK ss. Students get fa	owed.  4 amiliar with
NIE-HSC This course is d various kinds of	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and the statement of the sta	iences will be sho Z,ZK ss. Students get fa get familiar with h	owed.  4 amiliar with igher-order
NIE-HSC This course is d various kinds of s attacks.	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel	iences will be sho Z,ZK ss. Students get fa get familiar with h nformation leaka	owed.  4 amiliar with igher-orde ge.
NIE-HSC This course is d various kinds of attacks.	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and they also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel in Hardware Security	iences will be sho Z,ZK ss. Students get fa get familiar with h nformation leakar Z,ZK	wed.  4 amiliar with igher-order ge.  5
NIE-HSC This course is d various kinds of attacks.  NIE-HWB The course provide	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and a they also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel in the Hardware Security  Hardware Security  des the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards	iences will be sho Z,ZK is. Students get fa get familiar with h information leakar Z,ZK is against abuse of	owed.  4 amiliar with igher-orde ge.  5 f the system
NIE-HSC This course is d various kinds of s attacks.  NIE-HWB The course provicusing hardware r	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and a stack of they also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel in the Hardware Security  Hardware Security  Jes the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards neans. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Students	iences will be sho Z,ZK s. Students get fa get familiar with h information leakag Z,ZK s against abuse of its will gain knowl	wed.  4 amiliar with igher-orde ge.  5 f the system
NIE-HSC This course is d various kinds of s attacks.  NIE-HWB The course provicusing hardware r	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and a side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and a side channel in the sid	iences will be sho Z,ZK s. Students get fa get familiar with h information leakae Z,ZK s against abuse of its will gain knowl of the computer.	wed.  4 amiliar with igher-order ge.  5 f the system edge about
NIE-HSC This course is d various kinds of s attacks.  NIE-HWB The course provid using hardware r the course	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attack side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and they get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channel in Hardware Security des the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Student ryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions  Data Compression	iences will be sho Z,ZK s. Students get fa get familiar with h information leakae Z,ZK s against abuse of its will gain knowl of the computer. Z,ZK	wed.  4 amiliar with igher-orde ge.  5 f the system edge about
NIE-HSC This course is d various kinds of s attacks.  NIE-HWB The course proviousing hardware r the course the course state of	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attacks side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and side channels in the same of the side channels.  Hardware Security  des the knowledge needed for the analysis and design of computer systems security solutions. Students get an overview of safeguards neans. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Student ryptographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions  Data Compression  oduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data	iences will be sho Z,ZK s. Students get fa get familiar with h information leakae Z,ZK s against abuse of its will gain knowl of the computer. Z,ZK compression met	wed.  4 amiliar with igher-orde ge.  5 f the systemedge about 5 hods being
NIE-HSC This course is d various kinds of s attacks.  NIE-HWB The course proviousing hardware r the course the course state of	Side-Channel Analysis in Hardware edicated to so-called side-channel information leakage in hardware devices. It focuses on both theoretical analysis and practical attacks side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and side channels and they get deeper insight in power attacks. Students learn to implement various profiled and non-profiled attacks and side channels in the state of the side-channels. They also get practice in both designing the SCA countermeasures and analyzing the amount and characteristics of the side-channels. They will be able to safely use and design of computer systems security solutions. Students get an overview of safeguards means. They will be able to safely use and integrate hardware components into systems and test them for resistance to attacks. Student reprotographic accelerators, PUF, random number generators, smart cards, biometric devices, and devices for internal security functions.  Data Compression  oduced to the basic principles of data compression. They will learn the necessary theoretical background and get an overview of data. The overview covers principles of integer coding and of statistical, dictionary, and context data compression methods. In addition, students	iences will be sho Z,ZK s. Students get fa get familiar with h information leakae Z,ZK s against abuse of its will gain knowl of the computer. Z,ZK compression met	wed.  4 amiliar with igher-order ge.  5 f the systemedge about 5 hods being
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NIE-MPR Master Project Ζ 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. NIE-MTI Modern Internet Technologies Students learn advanced networking technologies and protocols for both local area networks and wide area networks. They get acquainted with routing techniques and transfer technologies of modern internet, including multimedia data transfer, with various types of network virtualization, and with last-mile security. NIE-MVI Computational Intelligence Methods Students will understand the basic methods and techniques of computational intelligence, which are based on traditional artificial intelligence, are parallel in nature and are applicable to solving a wide range of problems. The subject is also devoted to modern neural networks and the ways in which they learn and neuroevolution. Students will learn how these methods work and how to apply them to problems related to data extraction, management, intelligence in games and optimisation, etc. NIF-NON Nonlinear Continuous Optimization and Numerical Methods Z,ZK Students will be introduced to nonlinear continuous optimization, principles of the most popular methods of optimization and applications of such methods to real-world problems. They will also learn the finite element method and the finite difference method used for solving ordinary and partial differential equations in engineering. They will learn to solve systems of linear algebraic equations that arise from discretization of the continuous problems by direct and iterative algorithms. They will also learn to implement these algorithms sequentially as well as in parallel. **NIE-NSS** Normalized Software Systems ZK 5 Students will learn the foundations of normalized systems theory that studies the evolvability of modular structures based on concepts from engineering, such as stability from system theory and entropy from thermodynamics. Students will understand a set of principles that indicate where violations of stability and entropy-related issues occur in any given software architecture. In the second part of the course, students learn how to construct software architectures using a set of 5 design patterns called elements. These elements provide the core functionality of information systems in terms of storing data, executing actions, workflows, connectors, and triggers, while handling violations of the stability and entropy-related principles. This knowledge allows students to realize new levels of evolvability in software architectures. NIF-NUR User Interface Design Z,ZK 5 Students will understand the theorical background of human-computer interaction and user interface (UI) design, will learn formal description of UIs, formal user models, the fundamental notions and procesures. They get acquainted with graphical, speech, and multimodal Uls. Thanks to the gained knowledge, the students will be able to design advanced Uls Parameterized Algorithms Z,ZK There are many optimization problems for which no polynomial time algorithms are known (e.g. NP-complete problems). Despite that it is often necessary to solve these problems exactly in practice. We will demonstrate that many problems can be solved much more effectively than by naively trying all possible solutions. Often one can find a common property (parameter) of the inputs from practice-e.g., all solutions are relatively small. Parameterized algorithms exploit that by limiting the time complexity exponentially in this (small) parameter and polynomially in the input size (which can be huge). Parameterized algorithms also represent a way to formalize the notion of effective polynomial time preprocessing of the input, which is not possible in the classical complexity. Such a polynomial time preprocessing is then a suitable first step, whatever is the subsequent solution method. We will present a plethora of parameterized algorithm design methods and we will also show how to prove that for some problem (and parameter) such an algorithm (presumably) does not exist. We will also not miss out the relations to other approaches to hard problems such as moderately exponential algorithms or approximation schemes. **NIE-PDB** Advanced Database Systems Students orient themselves in problems of evaluation and optimization of SQL queries. The next part of the course deals with new concepts of database machines (so called NoSQL databases), with the related new data models (XML, graph databases, column databases) and languages for working with them (XQuery, XPath, CYPHER, Gremlin). The last part of the course deals with performance evaluation of database machines. This course is equivalent to the course MIE-PDB. 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. Parallel and Distributed Programming 21st century in computer architectures is primarily influenced by the shift of the Moore's law into parallelization of CPUs at the level of computing cores. Parallel computing systems are becoming a ubiquitous commodity and parallel programming becomes the basic paradigm of development of efficient applications for these platforms. Students get acquainted with architectures of parallel and distributed computing systems, their models, theory of interconnection networks and collective communication operations, and languages and environments for parallel programming of shared and distributed memory computers. They get acquianted with fundamental parallel algorithms and on selected problems, they will learn the techniques of design of efficient and scalable parallel algorithms and methods of performance evaluation of their implementations. The course includes a semester project of practical programming in OpenMP and MPI for solving a particular nontrivial problem. **NIE-PIS Advanced Information Systems** Z,ZK 5 Students learn the notion of business process logic and its formalization, with business process roles, business rules, and data processing, with the notion of service oriented company, enterprise services and service solution of business logic. They get acquainted with these notions also for the other types of ISs. They learn about agility and adaptivity and using of artificial intelligence methods for implementation of these ideas in ISs. They understand modern object-oriented methodologies for modelling of business processes, business rules, processed data, and enterprise ISs. They will get the rules and technologies for successful implementation of IS. NIE-PML Personalized Machine Learning 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. Reverse Engineering Students will learn fundamentals of reverse engineering of computer software (methods of executing and initializing programs, organization of executable files, work with third-party libraries). Special attention will be paid to C++. Students will also become familiar with the principles of debugging tools, disassemblers and obfuscation methods. Finally, the course will focus on code compression and decompression and executable file reconstruction. Pattern Recognition The aim of the module is to give a systematic account of the major topics in pattern recognition with emphasis on problems and applications of the statistical approach to pattern recognition. Students will learn the fundamental concepts and methods of pattern recognition, including probability models, parameter estimation, and their numerical aspects **NIE-SBF** System Security and Forensics Students will be introduced to various aspects of system security (principles of endpoint security, principles of security policies, security models, authentication concepts). Students will also learn about forensic analysis as a tool for investigating security incidents (techniques used by malicious software or attackers, forensic analysis techniques, and the importance of memory or file system artifacts for attack analysis and detection).

NIE SCE1	Computer Engineering Comings Moster I	Z	4
NIE-SCE1	Computer Engineering Seminar Master I mputer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to	_	
	dividually within the subject. Each student or group of students solves some interesting topics of digital design, reliability and resistance to		
	professional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar teacher		
artiolog and other p	semester.	o. The topice are it	101 0doi1
NIE-SCE2	Computer Engineering Seminar Master II	Z	4
	mputer Engineering is a (s)elective course for students who want to deal with deeper topics of digital design, reliability and resistance to	1	
	dividually within the subject. Each student or group of students solves some interesting topic with the selected supervisor. Part of the		
	professional literature and/or work in K N laboratories. The capacity of the subject is limited by the possibilities of the seminar teacher semester.	•	
NIE-SEP	World Economy and Business	Z,ZK	4
	uces students of technical university to the international business. It does that predominantly by comparing individual countries and k	1 ' 1	d economy.
Students get to	know about different religions and cultures, necessary for doing business in diverse societies as well as indexes of economic freedor	n, corruption and e	conomic
development, which	th are needed for the right investment decision. Seminars help to improve on the knowledge in the form of discussions based on indiv	ridual readings. It is	advised to
	take bachelor level of this course BIE-SEP as a prerequisite.		
NIE-SIB	Network Security	Z,ZK	5
The students will of	gain theoretical and practical knowledge and experience in the area of current security threats in computer networks, specifically abo	ut detection and de	efense. The
course explains	basic pricipals of security monitoring, packet-based and flow-based analysis, in order to detect anomalies and suspicious network tra	affic. The course for	cuses on
explanation and p	practical examples of various mechanisms of securing network infrastructure and detection in real time. The course covers general pr	incipals of handling	g detected
	security events (i.e. incident handling and incident response).		
NIE-SIM	Digital Circuit Simulation and Verification	Z,ZK	5
Aim of the cours	e is to acquaint the students with principles of digital circuit simulation at RTL (Register Transfer Level) and TLM (Transaction Level N	fodeling) levels and	d with the
	properties of proper tools. The course covers today recent verification methods, too.		
NIE-SWE	Semantic Web and Knowledge Graphs	Z,ZK	5
	learn the most recent concepts and technologies of the Semantic Web. The course will provide an overview of the Semantic Web tec	•	
practices for mod	delling, integration, publishing, querying and consumption of semantic data. The students will also gain skills in creation of knowledge	graphs and their s	ystematic
	quality assurance.		
NIE-SYP	Parsing and Compilers	Z,ZK	5
The module builds i	upon the knowledge of fundamentals of automata theory, formal language and formal translation theories. Students gain knowledge of va	arious variants and	applications
TEO	of LR parsing and are introduced to special applications of parsers, such as incremental and parallel parsing.	771	_
NIE-TES	Systems Theory	Z,ZK	5
•	Id has the ability to develop systems of incredible complexity (e.g., trains, microprocessors, airplanes, nuclear power plants). Howeve		
	ensuring the correct behavior of a given system have become critical. A key technique for mastering this complexity is the usage of m		-
aspects of the syst	tems that are important for the task at hand, and automated tools for analyzing those models. This subject will present theory and alg the modeling and analysis of complex systems.	onunns mai ionn u	ne basis ioi
NIE TOD		7 71/	_
NIE-TSP	Testing and Reliability  knowledge about circuit testing and about methods for increasing reliability and security. They will get practical skills to be able to pre	Z,ZK	5
_	ensitization and to use an ATPG for automatic test generation. They will be able to design easily testable circuits and systems with bu	-	
the intuitive path se	will be able to compute, analyze, and control the reliability and availability of the designed circuits.	iii-iii-seii-test equip	Jillelit. Tiley
NIE-VCC	Virtualization and Cloud Computing	Z,ZK	5
	n knowledge of architectures of large computer systems that are used in data centers and computer infrastructure of companies and	!	
_	rtualization principles, tools and technologies that serve to facilitate and automate configuration, testing and monitoring, and to efficie	-	
•	rameters of modern computer systems. Theoretically and practically, they will get acquainted with containerization as the most effect		•
	mplex computer systems and with specific technologies of cloud systems. Finally, they will learn the principles and gain practical skills in	٠,	•
J	and development tools (Continuous integration and development).		J
NIE-VPR	Research Project	Z	5
	g of the semester, a student reserves her/his final thesis topic and gets together with its supervisor. Together they decide on partial ta		
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. External			
Master these (MT) supervisor fills his/her assessment into the paper "Form to award assessment by an external Final theses (FT) supervisor" (for the courses BIE-BAP, MIE-MPR,			
MIE-DIP). Students	s, then, ensure that the assessment is registered into the information system (IS) by asking their internal FT opponent to award the a	ssessment to the I	S based on
the confirmation of	the external MT supervisor. In the case the FT opponent is external as well, the assessment will be registered to the IS by the head	of the department	responsible
for the topic of the	MT. 3. If the FT topic that the student has reserved is rather general, the immediate tasks the supervisor assigns to the student for the	ne upcoming semes	ster should
	aim at fine-tuning the FT topic so that the FTT will be complete and approvable at the end of the semester.		
NIE-VSM	Selected statistical Methods	Z,ZK	7

Classical theory of recursive functions and effective computability.

For updated information see <a href="http://bilakniha.cvut.cz/en/FF.html">http://bilakniha.cvut.cz/en/FF.html</a>
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NIE-VYC

Summary of probability theory; Multivariate normal distribution; Entropy and its application to coding; Statistical tests: T-tests, goodness of fit tests, independence test; Random processes
- stacionarity; Markov chains and limiting properties; Queuing theory

Z,ZK

Computability