UNIVERSITY OF DEBRECEN, FACULTY OF INFORMATICS

H-4028 Debrecen, Kassai Road 26., H-4002 Debrecen, P.O. box 400.
☎ 52/518-630, to@inf.unideb.hu

COMPUTER SCIENCE MSC

2021

Mode: Full-time training

Program Coordinator: Dr. György Vaszil (vaszil.gyorgy@inf.unideb.hu)

Mentor: Dr. Norbert Oláh (olah.norbert@inf.unideb.hu)

Qualification requirements

General requirements of the diploma are regulated by The Rules and Regulations of The University of Debrecen.

Work and Fire Safety and Physical Education

The courses of „Work and Fire Safety" and „Physical Education" are worth 1 - 1 credit, which must be completed in excess of the number of credits required for the diploma as specified in the training and outcome requirements of the degree.

Diploma credit requirements:

Mathematical and computer sciences:		36 credits
Compulsory courses:	21 credits	
Elective courses:	15 credits	
Informatical sciences:		42 credits
Compulsory courses:	15 credits	
Elective courses:	27 credits	
Professional Training:	9 credits	
Elective knowledge: („Mathematical and computer sciences" or „Informatical")		6 credits
Thesis work:		30 credits
Free choice:		6 credits
Total:		**120 credits**
Work and Fire Safety Training:		1 credit
Physical Education (1 semester):		1 credit

Professional training/Internship requirements

Professional training is a practice which is completed at a competent training place. It lasts for at least 6 weeks and 240 work hours.

It is a must to complete Professional training subject to issue the absolutorium (pre-degree certificate).

https://inf.unideb.hu/en/professional-training

Student can apply for Professional training after completing at least one semester.

Faculty of Informatics annex to the Academic and Examination Rules and Regulations of the University of Debrecen contains the procedure of the professional training.

The Thesis

During the studies, Student must write a thesis. Writing a thesis is a diploma requirement.

Thesis subject is mandatory to complete. The prerequisites to register for the Thesis subject are the followings:

- chose a thesis topic by the deadline.
  (Together with the supervisor the candidate writes a work plan in the maximum of two pages. The work plan describes the aim of the work, areas of expertise and the scheduling of the work.)
- the chosen topic is approved by the Educational Committee
- at least 30 completed credits.

Final Exam / State Exam

a., Requirements for Final Exam

1. Complete all the 120 credits required by the curriculum of program specialisation to have the degree of MSc program
2. Carry out the internship
3. Write and submit the Diploma Thesis

b., Process of the Final Exam

The Final Exam consists of an oral part only and the purpose is to examine the coherence of the professional knowledge.

F. The average from the grades of the oral exam (rounded to a whole number) consists of an item of the Mathematical and computer sciences knowledge and an item of the Informatical sciences knowledge. If the grade for any item is failed, the grade is failed, and the final examination is failed.

D1. Thesis defence. During the defence the candidate has to sum up the Thesis in a short presentation then s/he answers the questions from the referee of the Thesis and the members of the Committee.

D2. The grade for the thesis, which is determined by the Final Examination Committee taking into account the grade proposed by the thesis assessor.

Calculation of the final examination grade (**ZV**): ZV = (F+D1+D2)/3

If the grade D2 is failed, the candidate will not be allowed to sit the final examination.

If any of the grades of F or D1 are unsatisfactory, the final exam is also unsatisfactory. Only the component graded as unsatisfactory must be retaken in the retake of the final examination.

Grade of Diploma:
Diploma grade: in the case of a successful final examination, it is determined based on the average of the following results:

a) **SZ**: Average of the grades for the Thesis subject, the grade for the thesis assessment and the grades for the thesis defence in the final examination, rounded to two decimal places.

b) **F**: Average of the grades obtained in the final examination, rounded to a whole number.

c) **T**: the credit-weighted average of all compulsory and optional professional subjects completed during the course, except for 'Thesis 1' and 'Thesis 2', rounded to two decimal places.

Diploma grade = (0,3*SZ+0,2*F+0,5*T)

Based on the above average result, the qualification of the diploma is determined by the University of Debrecen's Academic and Examination Regulations, Section 31 (7). The diploma shall be assessed based on the calculation of the grade average as follows:

outstanding	4,81-5,00
excellent	4,51-4,80
good	3,51-4,50
satisfactory	2,51-3,50
pass	2,00-2,50

Mathematical and computer sciences, compulsory courses – needed 21 credits

Code	Subject name	Cre-dit	Type and number			Asses-ment	Prerequisites	Period	Semes-ter
			lec.	practice					
				sem.	lab				
INMPA0101-17 INMPA0101E INMPA0101G	Machine learning basics	6	2	2		E S			1
INMPA0102-21 INMPA0102E	Algorithms	3	2			E			1
INMPA0103-21 INMPA0103E INMPA0103L	Cryptography	6	2		2	E S			1
INMPA0205-17 INMPA0205E INMPA0205L	Optimization algorithms	6	2		2	E S			2

Informatical sciences, compulsory courses – needed 15 credits

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
INMPA0104-17 INMPA0104E	Information systems	3	2			E			1
INMPA0206-17 INMPA0206E INMPA0206L	Data mining	6	2		2	E S			2
INMPA0207-17 INMPA0207E INMPA0207L	Computer graphics	6	2		2	E S			2

Thesis work – needed 30 credits

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
INMPA0308-17 INMPA0308L	Thesis 1	15			10	PM			3
INMPA0409-17 INMPA0409L	Thesis 2	15			10	PM			4

Mathematical and computer sciences, elective courses – needed 15 credits

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
INMPA9910-17 INMPA9910L	Operation research	3			2	PM			1
INMPA9911-17 INMPA9911E INMPA9911G	Advanced inference methods	6	2	2		PM			2
INMPA9912-17 INMPA9912E	Logical algorithms	3	2			E			2
INMPA9913-17 INMPA9913E	Geometric modelling	3	2			E	INMPA0207-17		3
INMPA9914-17 INMPA9914E	Coding theory	3	2			E			3
INMPA9915-17 INMPA9915E	Theory of neural networks	3	2			E	INMPA0205-17		3
INMPA9916-17 INMPA9916E	Models of computation	3	2			E			3
INMPA9917-21 INMPA9917E INMPA9917L	Declarative programming	6	2		2	E S			4

Informatical sciences, elective courses – needed 27 credits

(At least one course from „Data science" block
and one course from „Information systems" block)

Professional Training

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
INMPA9997-21 INMPA9997G	Professional Training	9				PM			3

„Data science" block

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
INMPA9918-21 INMPA9918L	Geoinformatics	3			2	PM			1
INMPA9919-17 INMPA9919L	Advanced cloud computing	3			2	PM			2
INMPA9920-17 INMPA9920E INMPA9920L	Image processing and medical imaging	6	2		2	PM			2
INMPA9921-17 INMPA9921E INMPA9921L	Visualization and visual analytics	6	2		2	E S	INMPA0207-17		3
INMPA9922-17 INMPA9922L	Data science lab	3			2	PM	INMPA0101-17		4
INMPA9923-17 INMPA9923E INMPA9923L	Advanced machine learning	6	2		2	E S	INMPA0101-17		4
INMPA9932-21 INMPA9932E INMPA9932L	Advanced reinforcement learning	6	2		2	E S	INMPA0101-17	I	

„Information systems" block

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
INMPA9925-17 INMPA9925E INMPA9925L	Advanced XML technologies	6	2		2	PM			1
INMPA9926-17 INMPA9926L	NoSQL databases	3			2	PM			1
INMPA9927-17 INMPA9927L	Sensor networks and the internet of things	3			2	PM			1

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
INMPA9924-17 INMPA9924L	Advanced software architecture patterns	3			2	PM			3
INMPA9929-17 INMPA9929L	Text- and webmining	3			2	PM	INMPA0206-17		3
INMPA9930-17 INMPA9930L	Information systems in practice	6			2	PM	INMPA0104-17		4
INMPA9931-17 INMPA9931E INMPA9931L	Advanced software engineering	6	2		2	E S			4
INMPA9933-21 INMPA9933L	Software Engineering in the Industry	3			2	PM		I	
INMPA9934-21 INMPA9934L	Tools of parallel programming	3			2	PM		I	
INMPA9935-21 INMPA9935L	Rust: memory safe programming	3			2	PM		I	

Free choice – needed 6 credit

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				

* "Free choice" - Professional electives offered by the Faculty of Informatics and institutional electives offered by other faculties of the University of Debrecen.

Work and Fire Safety and Physical Education – needed 2 credits

must be completed in excess of the number of credits required
for the diploma as specified in the training and outcome requirements of the degree

Code	Subject name	Credit	Type and number			Assessment	Prerequisites	Period	Semester
			lec.	practice					
				sem.	lab				
	Work and Fire Safety	1				PM			1
	Physical Education	1				PM			

Exam types:
E exam
S signature
PM practical mark

COMPUTER SCIENCE MSC

Description of Subjects

Mathematical and Computer Science - Compulsory Courses

MACHINE LEARNING BASICS

INMPA0101-17

Semester: 1
Type: Lecture / Seminar
Number of Classes: 2+2+0
Credit: 6
Status: Obligatory
Assessment: Exam
Prerequisites: None
Responsible: Dr. András Hajdu

Topics:
To get familiar with the most important tasks, tools and techniques in machine learning. The subject focuses on solving realistic problems, to directly apply the basic concepts and results. The most important topics are exploiting useful information from a large amount of data for automatic classification and recognition purposes. The main mission of the course is to make the students familiar with the practical applicability of the concepts of this field to let the forthcoming, more specific, courses to be built upon on this knowledge. Basic concepts. Linear Algebra. Probability and Information Theory. Numeric Computations. Data Preprocessing. Dimensionality Reduction. Regression Models. Classification. Clustering. Association Rule Learning. Reinforcement Learning.

Compulsory/Recommended Readings:
- W. McKinney: Python for Data Analysis (1 ed.). O'Reilly Media, Inc. 2012.
- Christopher Bishop: Pattern Recognition and Machine Learning, Springer, 2006.
- D. Conway, J.M. White: Machine Learning for Hackers, O'Reilly Media, Inc., 2012.
- I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016.

ALGORITHMS

INMPA0102-21

Semester: 1
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Obligatory
Assessment: Exam
Prerequisites: None
Responsible: Dr. Tamás Herendi

Topics:
Complexity of conventional algorithms, complexity classes, NP-hard problems; optimization problems, dynamic programming; suboptimal solutions, real time algorithms; efficient data structures, heap, binomial heap, Fibonacci heap, search tree, red-black tree, B-tree; randomized algorithms, complexity of randomized algorithms, Las Vegas and Monte Carlo methods; parallel architectures, network and PRAM models, parallel complexities, communication costs; parallel programs, parallel sortings.

Compulsory/Recommended Readings:
- Sara Baase: Computer algorithms: introduction to design and analysis Pearson Education, 2009
- Thomas H. Cormen • Charles E. Leiserson • Ronald L. Rivest - Clifford Stein: Introduction to Algorithms; Third Edition, The MIT Press, Cambridge, Massachusetts, London, England, 2009
- Rajeev Motwani, Prabhakar Raghavan: Randomized Algorithms, Cambridge University Press (1995)

CRYPTOGRAPHY

INMPA0103-21

Semester:	1
Type:	Lecture / Laboratory
Number of Classes:	2+0+2
Credit:	6
Status:	Obligatory
Assessment:	Exam
Prerequisites:	None
Responsible:	Dr. Andrea Pintér-Huszti

Topics:
The mathematical model of secure information transmission. Basic notion of cryptography: plaintext, cyphertext, encryption- and decryption function, key. Pseudorandom number generation, stream cyphers. Basic principles for the construction of modern symmetric cryptosystems: the Feistel network; the method of permutation-substitution blocks, AES. Block cypher modes of operation.
Asymmetric encryptions: one way and one-way trapdoor functions, hash functions. The RSA algorithm. Public key cryptographic systems based on discrete logarithm and elliptic curve discrete logarithm problem. Digital signature schemes. ECDSA. TLS protocol. wireless security. Cloud and IoT security. Blockchain technology. Quantum computer-resistant algorithms of cryptography.

Compulsory/Recommended Readings:
- William Stallings, Cryptography and Network Security Principles and Practice (7. edition), 2021
- Jeffrey Hoffstein, Jill Pipher and Joseph H. Silverman, An Introduction to Mathematical Cryptography, Springer 2014, ISBN: 978-1-4939-1711-2

OPTIMIZATION ALGORITHMS

INMPA0205-17

Semester: 2
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Obligatory
Assessment: Exam
Prerequisites: None
Responsible: Dr. Ágnes Baran

Topics:
Differential calculus of multivariable functions, unconstrained and constrained extrema. Gradient methods, trust-region, Newton's method, quasi-Newton methods, conjugate gradient methods, nonlinear least-squares problems, stochastic optimization (simulated annealing).

Compulsory/Recommended Readings:
- Nocedal, Wright, Numerical Optimization, Springer, 2006, ISBN-10: 0-387-30303-0
- Gill, Murray, Wright, Practical Optimization, Emerald Group, 1982, ISBN-13: 978-0122839528

INFORMATION SYSTEMS

INMPA0104-17

Semester: 1
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Obligatory
Assessment: Exam
Prerequisites: None
Responsible: Dr. Márton Ispány

Topics:
Introduction: data models, ER and EER, and their mapping to the relation model. Practical database design methodology and use of UML diagrams. Object, object-relation and XML databases. NoSQL databases. Query processing and optimization, database tuning. Distributed databases. Modelling infor-mation systems. Architectures of Information systems. Data warehouse, OLAP. Information retrieval.

Compulsory/Recommended Readings:
- R. Elmasri, S. B. Navathe: Fundamentals of Database Systems, Addison Wesley, 2004,
- Sommerville: Software Enginering, Addison Wesley, 2004.

DATA MINING

INBPA0206-17

Semester: 2
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Obligatory
Assessment: Exam
Prerequisites: None
Responsible: Dr. Márton Ispány

Topics:
Definition of data mining and its role in the KDD process. Basic data mining tasks and techniques, the most important challenges. Datatypes, attributes, measuring scales, types of datasets. Issues of data quality, preprocessing. Explorative data analysis: statistics and graphical tools. Supervised learning: decision trees, regression, rule-based, nearest neighbour, Bayes classifiers, artificial neural networks (ANN), support vector machines (SVM), ensemble methods (bagging, boosting). Association rules. Distance and similarity. Clustering. K-means clustering and its variants. Hierarchical clustering. Density based methods: DBSCAN. Performance metrics and evaluation. Anomaly detection. Web-mining. Applications: spam-filtering, predictive maintenance services.

Compulsory/Recommended Readings:
- Pang-Nin Tan, Michael Steinbach, Vipin Kumar: Introduction to Data Mining. Pearson / Addison Wesley 2006. ISBN 0-321-32136-7
- Jiawei Han, Micheline Kamber: Data Mining: Concepts and Techniques. Elsevier 2006. ISBN 13: 978-1-55860-901-3

COMPUTER GRAPHICS

INBPA0207-17

Semester: 2
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Obligatory
Assessment: Exam
Prerequisites: None
Responsible: Dr. Roland Imre Kunkli

Topics:
The aim of computer graphics, historical overview. Visual display devices. The programmable graphical processing unit and pipeline. The used programming and shading languages' graphical possibilities. Drawing simple primitives. Fundamentals from linear algebra, projective and analytic geometry. Coordinate systems. Transformations and their classifications. Viewing. Orthogonal and central projections, axonometric projections. Viewing frustum. Visualizing surfaces generated by two variable (scalar valued) functions. Visualizing surfaces based on their parametric equation systems. Loading and using meshes. Data structures for surfaces. Visibility algorithms. Illumination models. Ambient, diffuse and specular lights. Light and material properties. Surface shading. Flat shading. Gouraud shading. Phong shading. Texturing. Ray casting, recursive ray tracing. Interpolating curves. Approximating curves. Hermite arcs with the GMT formula. Bézier curves. Joining curves, mathematical and geometrical continuities. Animations and motions. Incremental algorithms for drawing a line segment, a circle, or an ellipse. Filling and clipping algorithms. Overview of the most common information and scientific visualization problems and techniques. Interesting problems from the state of the art of computer graphics.

Compulsory/Recommended Readings:

- Tomas Akenine-Moller, Eric Haines, Naty Hoffman: Real-Time Rendering (3rd Edition). A K Peters/CRC Press, 2008., ISBN: 978-1568814247
- Donald D. Hearn, M. Pauline Baker: Computer graphics with OpenGL (3rd Edition). Prentice Hall, 2003., ISBN: 978-0130153906
- Steve Marschner, Peter Shirley: Fundamentals of Computer Graphics (4th Edition), A K Peters/CRC Press, 2015., ISBN-13: 978-1482229394
- John F. Hughes, Andries van Dam, Morgan McGuire, David F. Sklar, James D. Foley, Steven K. Feiner, Kurt Akeley: Computer graphics: principles and practice (3rd Edition). Addison-Wesley Professional, 2014., ISBN: 978-0321399526

OPERATION RESEARCH

INMPA9910-17

Semester: 1
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Ágnes Baran

Topics:
Introduction to the basic methods and algorithms of optimization and their applications. Blind search methods. Local search methods. Multiobjective optimization Genetic and evolutionary algorithms.

Compulsory/Recommended Readings:
- Cortez: Modern optimization with R, Springer, 2014.
- Michalewicz, Fogel: How to solve it: modern heuristic, Springer, 2004.

ADVANCED INFERENCE METHODS

INMPA9911-17

Semester: 2
Type: Lecture / Seminar
Number of Classes: 2+2+0
Credit: 6
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Tamás Kádek

Topics:
Structure of the compilers, reader, extender, grammars, parsing, syntax tree, domain specific languages, source-source compilers, interpreters.

Compulsory/Recommended Readings:
- Russel, Norvig: Artificial Intelligence: a modern approach, Prentice Hall, 2009.
- David L. Poole and Alan K. Mackworth: Artificial Intelligence: Foundations of Computational Agents, Cambridge University Press, 2010.

LOGICAL ALGORITHMS

INMPA9912-17

Semester: 2
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Optional
Assessment: Exam
Prerequisites: None
Responsible: Dr. Tamás Kádek

Topics:
Resolution in propositional and first order logic. Binary decision diagrams. Algorithms of SAT. Different systems of first order logical calculus. Herbrand's models. The problems of decidability in first order logic. The fundamental principles of logical programming. Verification of sequential programs.

Compulsory/Recommended Readings:
- Modechai Ben-Ari: Mathematical Logic for Computer Science, Third edition, Springer-Verlag London, 2012, DOI 10.1007/978-1-4471-4129-7
- M. Huth, M. D. Ryan: Logic in Computer Science: Modelling and Reasoning about Systems (Second Edition), Cambridge University Press, 2004
- E. Mendelson: Introduction to Mathematical Logic (Fifth edition), Chapman and Hall/CRC, 2009

GEOMETRIC MODELLING

INMPA9913-17

Semester: 3
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Optional
Assessment: Exam
Prerequisites: INMPA0207-17 (Computer graphics)
Responsible: Dr. Ildikó Papp

Topics:
The goal of the subject is to overview advanced applied mathematical and computational geometric methods and algorithms for the mathematical description of curves and shapes. The methods are used to in computer graphics and computer aided design and manufacturing.
Related topics:
Projective and differential geometrical background of curve and surface modeling, Point cloud and processing possibilities: Mesh Repair, Remeshing, Mesh Editing, Advanced knowledge of Bézier and B-spline (NURBS) curves and surfaces, Advanced techniques: Subdivision, Skinning and offset techniques, Sweep surfaces; Smoothing and blending curves and surfaces, Special projecting models, Reconstruction based on images, Fundamentals of modeling for 3D printing.

Compulsory/Recommended Readings:
- Hoschek J., Lasser D. Fundamentals of computer aided geometric design, A. K. Peters, Ltd., Wellesley, 1993. ISBN-10: 1568810075
- David Salomon: Curves and Surface for Computer-Aided Geometric Design, Springer, 2006. ISBN-10: 0387241965
- Tomas Akenine-Moller, Eric Haines, Naty Hoffman: Real-Time Rendering, 3 edition, 2008, ISBN-10: 1568814240, A K Peters/CRC Press
- Mario Botsch, Mark Pauly, Christian Rossl, Stephan Bischoff, Leif Kobbelt: Geometric Modeling Based on Triangle Meshes, 2006, http://lgg.epfl.ch/publications/2006/botsch_2006_GMT_sg.pdf
- Alan Watt: 3D Computer Graphics, Addison-Wesley, 3rd Edition, 1999. ISBN-10: 0201398559

CODING THEORY

INMPA9914-17

Semester: 3
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Optional
Assessment: Exam
Prerequisites: None
Responsible: Dr. Tamás Herendi

Topics:
Shannon's communication model; uniquely decodable codes, completeness of codes; prefix codes; measurement of information; Shannon-entropy; optimal encoding, Huffmann codes; efficiency, ideal codes. Data compression methods, LZ77 és LZ78, LZW; FFT, wavelet transformation, lossy compression principles. Basic concepts of error correcting codes, block codes, error detecting and error correction, code distance; linear codes, systematic encoding, generating and parity check matrix, code bounds, syndrome and its use for error correction; Hamming codes, Reed-Solomon codes; cyclic codes; code combinations.

Compulsory/Recommended Readings:
- Elwyn R. Berlekamp Algebraic Coding Theory, World Scientific Publishing (2014)
- McEliece, R. The Theory of Information and Coding. Cambridge, (2002)

THEORY OF NEURAL NETWORKS

INMPA9915-17

Semester: 3
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Optional
Assessment: Exam
Prerequisites: INMPA0205-17 (Optimization algorithms)
Responsible: Dr. István Fazekas

Topics:
The scope of problems that can be solved by neural networks. Main types of neural networks. Supervised and unsupervised learning. Structure and training of the multilayer perceptron (MLP). Activation functions, loss functions. Training MLP: error back-propagation. Gradient descent and conjugate gradient methods, quasi-Newton method, Levenberg-Marquardt method. Properties of MLP. Radial-basis function networks (RBF). Penalty fuctions, regularization. Generalized radial-basis function networks. Kernel function methods. The problem and methods of deep learning. The autoencoder. Support vector machines (SVM). The optimal hyperplane. SVM for separation and approximation. The structure and applications of the convolutional network. Error back-propagation for convolutional networks. Recurrent networks. Long short-term memory.

Compulsory/Recommended Readings:
- Haykin, S.: Neural Networks. A Comprehensive Foundation. Prentice hall. New Jersey, 1999. ISBN 0-13-273350-1
- Matlab Neural Network Toolbox. The Mathworks, Inc.
- Ian Goodfellow and Yoshua Bengio and Aaron Courville: Deep Learning. MIT Press, 2016.

MODELS OF COMPUTATION

INMPA9916-17

Semester: 3
Type: Lecture
Number of Classes: 2+0+0
Credit: 3
Status: Optional
Assessment: Exam
Prerequisites: None
Responsible: Dr. György Vaszil

Topics:
The course covers the basics of some conventional and unconventional computational models: parallel and regulated rewriting systems, grammar systems, DNA computation, membrane computation, reversible computing models.

Compulsory/Recommended Readings:
- M. Amos: Theoretical and Experimantal DNA Computation. Springer, 2005
- J. Dassow, Gh. Paun: Regulated rewriting in formal language theory. Springer, 1989.
- C. Martin-Vide, V. Mitrana, Gh. Paun (szerk.): Formal Languages and Applications. Springer, 2004.
- J. Shallit: A second course in formal languages and automata theory. Cambridge University

DECLARATIVE PROGRAMMING

INMPA9917-21

Semester: 4
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Optional
Assessment: Exam
Prerequisites: None
Responsible: Dr. Péter Battyányi

Topics:
The untyped lambda calculus. Reduction, normal form, confluence. Arithmetics in the lambda calculus, fixpoint operators. Partial recursive functions. Simply-typed lambda calculus, Curry and Church typing. The Curry-Howard isomorphism. Representations of data types, elements of the implementation of functional languages. Weak and strong normalization. Type inference. Evaluation strategies, standardization, normal forms. Separation in the lambda calculus. Combinatory logic. First- and second order logic, extensions of the Curry-Howard isomorphism. The connection between reduction and cut elimination. Classical logic and control operators. Polymorphic types, System F. Recusive types, subtyping. Some more questions on the implementation of functional languages. Further topics in automated theorem proving.

Compulsory/Recommended Readings:
- Benjamin C. Pierce: Types and Programming Languages, The MIT Press, 2002, 978-0262162098
- M. H. Sorensen, P. Urzyczyn: Lectures on the Curry-Howard Isomorphism, Elsevier Sci-ence, 2006, 978-0444520777
- Aaron Stump: Programming Language Foundations, Wiley, 2013, 978-1118007471

Informatical Sciences - Elective Courses

Data Science Block

GEOINFORMATICS

INMPA9918-21

Semester: 1
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Marianna Bodroginé Zichar

Topics:
Characteristics and types of spatial data, and databases. Types of spatial analysis, designing and implementing geospatial analysis tools. Webmap types, webmap services and location based services. OGC geospatial standards (WMS, WFS, GML, SF-SQL), their characteristics, and usage. Working with gis file types designed for supporting web applications. Developing interactive, webgis applications using freeware software products. Methods for evaulating aerial and satellite images, working with public data sets and open APIs.

Compulsory/Recommended Readings:
- Longley, Paul A. and Goodchild, M. F.: Geographic Information Science and Systems, Wiley, 2015, 978-1118676950
- Hassan A. Karimi (Editor), Bobak Karimi (Editor): Geospatial Data Science Techniques and Applications, CRC Press, 2018, 978-1138626447
- Documentation of the GIS software, programming language, and API.

ADVANCED CLOUD COMPUTING

INMPA9919-17

Semester: 2
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Tamás Bérczes

Topics:
The goal of the subject is to provide an introduction to cloud computing (C2) topics, architecture, service elements, mechanisms and technologies. The course illustrates the cloud types and ser-vice models of cloud-based technologies and management methods. The students become famil-iar with the subject of virtualization techniques used in practice, data storage and transmission security issues. Described methods of network infrastructure in a virtualized environment, plan-ning and present practical implementations through case-studies.

Compulsory/Recommended Readings:
- Anthony T. Velte, Toby J. Velte, Robert Elsenpeter (2010): Cloud Computing: A Practical Approach, ISBN: 978-0-07-162695-8
- Igor Faynberg, Hui-Lan Lu, Dor Skuler (2016): CLOUD COMPUTING Business Trends and Technologies, John Wiley & Sons Ltd
- "Thomas Erl, Robert Cope, Amin Naserpour (2015): Cloud Computing Design Patterns, Arcitura Education Inc. ISBN-13: 978-0-13-385856-3, ISBN-10: 0-13-385856-1"

IMAGE PROCESSING AND MEDICAL IMAGING

INMPA9920-17

Semester: 2
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Attila Fazekas

Topics:
To get familiar with the most important tasks, tools and techniques related to image processing. The subject focuses on solving realistic problems, to directly apply the basic concepts and results.
Sampling, pixel operators, segmentation, mathematical morphology, linear filters, image transforms, multi-resolution image processing, noise reduction, restoration, feature extraction. Medical imaging, image reconstruction, direct and undirect visualisation. Databases and software tools.

Compulsory/Recommended Readings:
- V. Hlavac, M. Sonka, R. Boyle: Image Processing, Analysis, and Machine Vision, Cengage Learning, 2014.
- J. L. Prince, J. Links, Medical Imaging Signals and Systems, Pearson Education, 2014.
- K. Fukunaga, Introduction to Statistical Pattern Recognition, Academic Press, 1990.
- C. Solomon, T. Breckon: Fundamentals of Digital Image Processing: A Practical Approach with Examples in Matlab, Wiley-Blackwill, 2010.

VISUALIZATION AND VISUAL ANALYTICS

INMPA9921-17

Semester: 3
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Optional
Assessment: Exam
Prerequisites: INMPA0207-17 (Computer graphics)
Responsible: Dr. Roland Imre Kunkli

Topics:
The purpose, principles and history of visualization and visual analytics. Practicing the usage of the used programming library and software through simple examples. Data types, datasets, data models and attributes. Data abstraction. Mental and visualization models. Visual variables. Actions, tasks, and goals. Task abstraction. Visualization design. Exploratory data analysis. Multidimensional data visualization. Data wrangling. Visual and graphical perception. Visualizing temporal and geospatial data. Visualizing trees, graphs, networks and texts. Interaction. Animation. Color. Scalability. Dimensionality reduction. Databases, tools and software for visual analytics. Storytelling. Classification and clustering. Collaboration. Validation and evaluation. Future trends in information visualization and visual analytics. Analysis case studies.

Compulsory/Recommended Readings:
- Tamara Munzner: Visualization Analysis and Design, A K Peters/CRC Press, 2014, ISBN: 978-1466508910
- Katy Borner, David E. Polley: Visual Insights: The Practical Guide to Making Sense of Data, The MIT Press, 2014, ISBN: 978-0262526197
- Edward R. Tufte: The Visual Display of Quantitative Information (2nd Edition), Graphics Pr, 2001, ISBN: 978-0961392147
- D. Keim, J. Kohlhammer, G. Ellis, F. Mansmann (editors): Mastering the information age - Solving problems with visual analytics. Eurographics Association, 2010., URL: http://www.vismaster.eu/wp-content/uploads/2010/11/VisMaster-book-lowres.pdf
- James J. Thomas (editor), Kristin A. Cook (editor): Illuminating the Path: The Research and Development Agenda for Visual Analytics, National Visualization and Analytics Center, 2005, ISBN: 978-0769523231

DATA SCIENCE LAB

INMPA9922-17

Semester: 4
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: INMPA0101-17 (Machine learning basics)
Responsible: Dr. András Hajdu

Topics:
To get familiar with the most important challenges, tasks, tools and techniques related to data science in research and industry. The subject focuses on solving realistic problems, to directly apply the basic concepts and results. There is a strong intention to co-operate also with industrial partners within R&D projects. Challenges is Data Science (Research and Industry). Case Study, Image Recognition. Case Study, Processing Big Data. Recommender Systems. Digital Advertisements, Internet Search. Gaming. Fraud and Risk Detection. Route Planning, Delivery, Optimization. Robotics. Autonomous Driving. Project Work. Industrial Projects.

Compulsory/Recommended Readings:
- W. McKinney: Python for Data Analysis (1 ed.). O'Reilly Media, Inc. 2012.
- Christopher Bishop: Pattern Recognition and Machine Learning, Springer, 2006.
- D. Conway, J.M. White: Machine Learning for Hackers, O'Reilly Media, Inc., 2012.
- I. Goodfellow, Y. Bengio, A. Courville: Deep Learning, MIT Press, 2016.

ADVANCED MACHINE LEARNING

INMPA9923-17

Semester: 4
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Optional
Assessment: Exam
Prerequisites: INMPA0101-17 (Machine learning basics)
Responsible: Dr. Balázs Harangi

Topics:
Introduction to deep learning. Logistic regression. Neural networks. Feedforward networks. Backpropagation algorithm. Activation functions. Optimization. Stochastic gradient method and its variants. Momentum. Energy functions. Weight initialization. Regularization. Convolutional neural networks. Pooling layers. Dropout. Normalization. Representation learning. Visualization. Deep Convolutional neural networks. Recurrent neural networks. Advanced recurrent and recursive neural networks. Autoencoders. Generative models. Ensemble methods.

Compulsory/Recommended Readings:
- Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning, MIT Press, 2016
- Ludmila I. Kuncheva: Combining Pattern Classifiers: Methods and Algorithms, Second Edition, Wiley, 2014

ADVANCED REINFORCEMENT LEARNING

INMPA9932-21

Semester: I
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Optional
Assessment: Exam
Prerequisites: INMPA0101-17 (Machine learning basics)
Responsible: Dr. Balázs Harangi

Topics:
By completing the course, students will gain knowledge in various reinforcement learning (RL) topics, learn about the theoretical background, the possible applications and how RL can be applied in practice. Students will gain theoretical and practical experience in the following areas: the basics of reinforcement learning; formalizing problems as Markov Decision Processes; key concepts and terminology; states and observations; dynamic programming; action spaces; policies; deterministic policies; stochastic policies; trajectories; reward and return; the RL problem; value functions; the optimal Q-function and optimal operation; model-free and model-based RL; policy optimization; Q-learning; RL algorithms. The algorithms presented in the course will be used in a variety of interactive real-world environments (OpenAI Gym, Unity ML-Agents), providing students with important hands-on experience in implementing, fine-tuning, and debugging algorithms and custom environments.

Compulsory/Recommended Readings:
- Richard S. Sutton and Andrew G. Barto: Reinforcement Learning: An Introduction, MIT Press, 2020.
- Ian Goodfellow, Yoshua Bengio, Aaron Courville: Deep Learning, MIT Press, 2016.
- Szepesvári, C. (2010). Algorithms for reinforcement learning. Synthesis lectures on artificial intelligence and machine learning, 4(1), 1-103.
- Graesser, L., & Keng, W. L. (2019). Foundations of deep reinforcement learning: theory and practice in Python. Addison-Wesley Professional

ADVANCED XML TECHNOLOGIES

INMPA9925-17

Semester:	1
Type:	Lecture / Laboratory
Number of Classes:	2+0+2
Credit:	6
Status:	Optional
Assessment:	Practical mark
Prerequisites:	None
Responsible:	Dr. Péter Jeszenszky

Topics:
The goal of the course is to introduce students to XML standards that are widely used in the industry, and to demonstrate their use and the use of developer tools in the field. Topics discussed in the classes: XML schema languages (XML Schema, RELAX NG), XPath, XSLT, XProc, XQuery, native and embedded XML databases, JSON as an alternative to XML, storing XML documents in relational databases, contemporary XML applications and related developer tools (e.g., Atom, DocBook, SVG, XMPP).

Compulsory/Recommended Readings:
- Priscilla Walmsley: Definitive XML Schema, 2nd ed., Prentice Hall, 2012., ISBN: 978-0132886727,
- Doug Tidwell: XSLT, 2nd ed., O'Reilly Media, 2008., ISBN: 978-0596527211,
- Priscilla Walmsley: XQuery: Search Across a Variety of XML Data, 2nd ed., O'Reilly Media, 2016., ISBN: 978-1491915103.
- Erik Siegel, Adam Retter: eXist: A NoSQL Document Database and Application Platform, O'Reilly Media, 2014., ISBN: 978-1449337100,
- Norman Walsh, XML Pipelines, 2010, http://xprocbook.com/

NOSQL DATABASES

INMPA9926-17

Semester: 1
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. László Szathmáry

Topics:
NoSQL data models; NoSQL database management systems. Features of the MongoDB document-oriented system; JSON format. Installing MongoDB; command-line interface; CRUD operations. Using the CRUD operations from applications. Schema design in MongoDB. Performance; indexes; administrative tools. Aggregation framework. The Redis key/value store; installation; command-line interface. Using Redis from applications. The Neo4j graph-based system; components of Neo4j. Installing Neo4j; command-line interface; web interface. The Cypher query language. Using Neo4j from applications. Column stores. Summary, outlook.

Compulsory/Recommended Readings:
- Kristina Chodorow: MongoDB: The Definitive Guide. O'Reilly, 2013.
- Josiah L. Carlson: Redis in Action. Manning, 2013.
- Gregory Jordan: Practical Neo4j. Apress, 2014.

SENSOR NETWORKS AND THE INTERNET OF THINGS

INMPA9927-17

Semester: 1
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Attila Buchman

Topics:
Intelligent sensors, sensor networks and connection to IoT. Intelligent sensors hardware architecture. Sensor network architectures. Design issues. Wireless Sensor Networks standardization: IEEE 802.15.4,.ZigBee and Bluethoot LE protocol stack. Typical sensor networking case studies (health, engineering applications, environmental protection, smart home, etc)

Compulsory/Recommended Readings:
- Edgar H., Jr. Callaway, Edgar H. Callaway, Wireless Sensor Networks: Architectures and Protocols, Auerbach Publications, 2003
- H. Karl, A. Willig, „Protocols and Architectures for Wireless Sensor Networks", John Wiley & Sons Ltd, 2005

ADVANCED SOFTWARE ARCHITECHTURE PATTERNS

INMPA9924-17

Semester: 3
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. László Szathmáry

Topics:
In the class the students are introduced to the common software architecture patterns (SOA, Mikrokernel Architecture Pattern, Microservice Architecture Pattern, Cloud Architecture Pattern). Each pattern includes a full explanation of how it works, explains the pattern's benefits and considerations, and describes the circumstances and conditions it was designed to address.

Compulsory/Recommended Readings:
- Mark Richards: Software Architecture Patterns, O'Reilly, 2015
- Sam Newman: Building Microservices, O'Reilly, 2015
- Thomas Erl: Service-Oriented Architecture: Analysis and Design for Services and Microservices (2nd Edition), Prentice Hall, 2016.december 22.
- Andreas Wittig, Michael Wittig: Amazon Web Services in Action, Manning Publications, 2015
- Thomas Erl: Cloud Computing: Concepts, Technology & Architecture, Prentice Hall, 2013.

TEXT- AND WEB-MINING

INMPA9929-17

Semester: 3
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: INMPA0206-17 (Data mining)
Responsible: Dr. Márton Ispány

Topics:
Preprocessing, modelling and representation in text mining. Information retrieval. Classification. Segmentation. Latent semantic indexing. Web structure mining, web crawlers. Social network analysis, indexing, PageRank and HITS. Web usage mining. Opinion mining and sentiment analysis Recommendation systems and collaborative filtering. Data streams. Summary and applications.

Compulsory/Recommended Readings:
- Ronen Feldman, James Sanger, The Text Mining Handbook. Cambridge University Press, 2007,
- Bing Liu, Web Data Mining. Springer, 2011,
- Documentation of the applied data mining software.

INFORMATION SYSTEMS IN PRACTICE

INMPA9930-17

Semester: 4
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: INMPA0104-17 (Information systems)
Responsible: Dr. Márton Ispány

Topics:
Practical application of information systems: ERP systems, smart city and smart campus solutions.

Compulsory/Recommended Readings:
- R. Elmasri, S. B. Navathe: Fundamentals of Database Systems, Addison Wesley, 2004,
- Sommerville: Software Enginering, Addison Wesley, 2004.

ADVANCED SOFTWARE ENGINEERING

INMPA9931-17

Semester: 4
Type: Lecture / Laboratory
Number of Classes: 2+0+2
Credit: 6
Status: Optional
Assessment: Exam
Prerequisites: None
Responsible: Dr. Attila Adamkó

Topics:
Introducing students into the advanced part of Software Engineering aspects. Highlighting principles, methods and XML standards that are widely used in the industry. In the practical part the goal is to demonstrate their use and the use of developer tools in this field.

Compulsory/Recommended Readings:
- Sommerville: Software Enginering, Addison Wesley, 2007
- Rozanski, N., Woods E., Software Systems Architecture: Working With Stakeholders Using Viewpoints and Perspectives, Addison Wesley, 2005.
- Rumbaugh J., Jacobson I., Booch G., Unified Modeling Language Reference Manual, The, 2nd Edition, Addison Wesley, 2004.
- Evans, E., Domain-Driven Design: Tackling Complexity in the Heart of Software, Addison Wesley, 2003

SOFTWARE ENGINEERING IN THE INDUSTRY

INMPA9933-21

Semester:
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Tamás Kádek

Topics:
The aim of the course is to discuss programming paradigms, advanced language elements, frameworks, technologies, methodologies, and algorithms that currently play a leading role in software development. The course follows industry trends to enable students to acquire advanced theoretical and practical knowledge of current technologies and their methods and tools. Students will learn about the most important web standards, popular frontend and backend technologies, their related environments, programming languages, and paradigms. Finally, students apply the knowledge acquired during the course to a project. In addition to the basics of web development, the subject also provides an opportunity to learn about other areas, such as software testing, game development, and agile methodologies.

Compulsory/Recommended Readings:
- Ian Sommerville. Software Engineering. 10th ed. Pearson Education, 2015.
- Jez Humble, David Farley. Continuous Delivery: Reliable Software Releases through Build, Test, and Deployment Automation. 1st ed. Pearson Education, 2010.
- Arnaud Lauret. The Design of WEB APIs. 1st ed. Manning Publication, 2019.

TOOLS OF PARALLEL PROGRAMMING

INMPA9934-21

Semester:
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Róbert Tornai

Topics:
Modern hardware (CPU–GPU) usually support multi core and multithread executing. Ac-cording to this, parallel algorithms are essential part of the toolkit of the up-to-date pro-grammer to maximalize the utilization of the resources. During the semester the SIMD in-struction set will be discussed in order to give full payload to the execution units of one thread. Multi core architectures will be handled by multithreading. With the help of GPGPU the video cards can be used for general purpose programming. Using these methods context-sensitive and context-free image processing tasks can be solved. Furthermore, the course covers methods for: histogram, color LUT, hashing, bitonic sort, multithreaded qsort and search. For visualization particle systems and raytracing will be implemented. The covered mathematical problems will include the Mandelbrot set computing, vector (sum, scalar or dot product) or matrix (multiplication; unity or identity, diagonal and symmetry check) op-erations, solving systems of linear equations and the FFT algorithm. In this way, all tools are available for students to complete a practical project work during the semester and get a new programming perspective that is useful in corporate environment.

Compulsory/Recommended Readings:

- Mara Bos (Author): Rust Atomics and Locks: Low-Level Concurrency in Practice, O'Reilly Media; 1st edition (February 7, 2023)
- Matt Pharr (Editor), Randima Fernando (Editor), Tim Sweeney (Foreword): GPU Gems 2: Programming Techniques For High-Performance Graphics And General-Purpose Computation, Addison-Wesley Professional; First Edition (January 1, 2005)
- Brian L. Troutwine: Hands-On Concurrency with Rust: Confidently build memory-safe, parallel, and efficient software in Rust, Packt Publishing; 1st edition (May 31, 2018)
- Guillaume Gomez, Antoni Boucher: Rust Programming By Example: Enter the world of Rust by building engaging, concurrent, reactive, and robust applications, Packt Publis-hing; 1st edition (January 11, 2018)

RUST: MEMORY SAFE PROGRAMMING

INMPA9935-21

Semester:
Type: Laboratory
Number of Classes: 0+0+2
Credit: 3
Status: Optional
Assessment: Practical mark
Prerequisites: None
Responsible: Dr. Róbert Tornai

Topics:
Rust is a memory safe and quick general purpose programming language that is suitable for creating even system level applications. In the latest times it is not only in the forefront of Android development, but it gains ground in the kernel of Linux and Windows. During the course students can learn Rust starting from the primitives through custom types, variable bindings and conversion until we reach expressions and the flow of control mechanism. Functions and modules are stored in crates inside the cargo system. The error handling and usage of standard packages are made complete with testing and unsafe operations. In this way, all tools are available for students to complete a system level personal practical project work during the semester.

Compulsory/Recommended Readings:

- Prabhu Eshwarla: Rust Servers, Services, and Apps, Manning (August 15, 2023)
- Jim Blandy, Jason Orendorff, Leonora Tindall: Programming Rust: Fast, Safe Systems Development, O'Reilly Media; 2nd edition (July 20, 2021)
- Steve Klabnik, Carol Nichols: The Rust Programming Language, No Starch Press; 2nd edition (February 28, 2023)
- Tim McNamara: Rust in Action, Manning; 1st edition (August 10, 2021)
- Maxwell Flitton: Rust Web Programming: A hands-on guide to developing, packaging, and deploying fully functional Rust web applications, Packt Publishing; 2nd edition (January 27, 2023))