I. Doctoral School of Informatics

Discipline: informatics/computer science
Level: doctoral (PhD)
Aim of the programme: to give regular courses to students and prepare them for obtaining a scientific degree, and to offer them teaching experience in higher education
Duration of the programme: 8 semesters
Type of the programme: full-time education
Finances: limited number of state scholarships, otherwise tuition fee
Entry requirements: MSc degree and entrance examination
Language requirements: one complex (B2) intermediate level state-accredited language exam
Certificate at the end of the training: pre-degree certificate
Full credit requirements: 240 credits
Ways of obtaining credits: scholastic credits (min: 24, max: 54)
teaching (min: 0, max: 48)
research (min: 150, max: 216)

The required credits that must be fulfilled by the 4th semester are stated in the ELTE Doctoral Regulations. A complex exam is required afterwards.
Until the end of the fourth semester at least one of the complex exam courses is compulsory. Credits cannot be given after the successful complex exam in the Scholastic training module.

The doctoral training programmes

Doctoral School of Informatics / Foundations and methodology of informatics

Doctoral School of Informatics / Information systems

Doctoral School of Informatics / Numerical and symbolical calculus

Doctoral School of Informatics / Informatics teaching methodology

Scholastic training module (min: 24, max: 54 credits)

INFPHD005 Software Quality Management
6 credits, lecture, obligatory optional, not reproducible
INFPHD008 Seminar on search and communicational complexity
6 credits, practice, obligatory optional, not reproducible
INFPHD009 Surface reconstruction by computer
6 credits, lecture, obligatory optional, not reproducible
INFPHD015 Research Topics in Autonomic Systems
6 credits, lecture, obligatory optional, not reproducible
INFPHD021 Advanced database systems I. (Fundamentals of Databases I-II.)
6 credits, lecture, obligatory optional, not reproducible
INFPHD022 Advanced database systems II. (Fundamentals of Databases II-III.)

6 credits, lecture, obligatory optional, not reproducible

INFPHD023 Data mining

6 credits, lecture, obligatory optional, not reproducible

INFPHD032 Type theory

6 credits, lecture, obligatory optional, not reproducible

INFPHD034 Analysis of Algorithms and Data Structures I.

6 credits, lecture, obligatory optional, not reproducible

INFPHD035 Comparative analysis of Programming Languages

6 credits, lecture, obligatory optional, not reproducible

INFPHD037 Artificial Neural Nets

6 credits, lecture, obligatory optional, not reproducible

INFPHD042 Introduction to Computer Algebra

12 credits, lecture, obligatory optional, not reproducible

INFPHD048 Analysis of Algorithms and Data Structures II.

6 credits, lecture, obligatory optional, not reproducible

INFPHD052 Queueing theory

6 credits, lecture, obligatory optional, not reproducible

INFPHD061 Research methodology

6 credits, lecture, obligatory optional, not reproducible

INFPHD073 Extremal Families of Subsets seminar

6 credits, practice, obligatory optional, not reproducible

INFPHD078 Cryptography seminar

6 credits, practice, obligatory optional, not reproducible

INFPHD080 Systems of language processors: formal –language-theoretic models of multi-agent systems

6 credits, lecture, obligatory optional, not reproducible

INFPHD102 Bio-inspired Computation: Membrane Systems

6 credits, lecture, obligatory optional, not reproducible

INFPHD128 Research areas of generative programming

6 credits, lecture, obligatory optional, not reproducible

INFPHD142 M-Learning

6 credits, lecture, obligatory optional, not reproducible

INFPHD143 Teaching of informatics methodology

6 credits, lecture, obligatory optional, not reproducible

INFPHD156 R&D questions of innovative TEL (Technology Enchanted Learning)

6 credits, lecture, obligatory optional, not reproducible

INFPHD157 Search and communication complexity, Seminar, II

6 credits, lecture, obligatory optional, not reproducible

INFPHD158 Search and communication complexity, Seminar, III

6 credits, lecture, obligatory optional, not reproducible

INFPHD160 Theory of informatics curriculum

6 credits, lecture, obligatory optional, not reproducible

INFPHD167 Nonlinear phenomenon on lattice

6 credits, lecture, obligatory optional, not reproducible

INFPHD179 Chapters of informatics methodology research seminar I.

6 credits, practice, obligatory optional, not reproducible

INFPHD181 Computer vision

6 credits, lecture, obligatory optional, not reproducible

INFPHD182 Artificial intelligence techniques in robotics

6 credits, lecture, obligatory optional, not reproducible

INFPHD184 Chapters of informatics methodology research seminar II.

6 credits, practice, obligatory optional, not reproducible

INFPHD185 Chapters of informatics methodology research seminar III.

6 credits, practice, obligatory optional, not reproducible

INFPHD187 Dynamical systems with applications using computer algebra

6 credits, lecture, obligatory optional, not reproducible

INFPHD190 Educational programming languages

6 credits, lecture, obligatory optional, not reproducible

INFPHD196 Models of operations research

6 credits, lecture, obligatory optional, not reproducible

INFPHD197 Multiple objective optimization

6 credits, lecture, obligatory optional, not reproducible

INFPHD407 Software Testing

6 credits, lecture, obligatory optional, not reproducible

INFPHD413 Principles of Real Analysis

6 credits, lecture, obligatory optional, not reproducible

INFPHD417 Research fields of interactive media

6 credits, lecture, obligatory optional, not reproducible

INFPHD421 Mobil Ad Hoc Networks

6 credits, lecture, obligatory optional, not reproducible

INFPHD423 Parallel computing in discrete mathematical modelling

6 credits, lecture, obligatory optional, not reproducible

INFPHD427 Peer-to-Peer Networks

6 credits, lecture, obligatory optional, not reproducible

INFPHD433 Fourier Calculus I.

6 credits, lecture, obligatory optional, not reproducible

INFPHD434 Fourier Calculus II.

6 credits, lecture, obligatory optional, not reproducible

INFPHD435 Current Trends in Logic Programming

6 credits, practice, obligatory optional, not reproducible

INFPHD436 Scientific Databases

6 credits, lecture, obligatory optional, not reproducible

INFPHD437 Variational methods in practice

6 credits, lecture, obligatory optional, not reproducible

INFPHD438 Requirements Engineering

6 credits, lecture, obligatory optional, not reproducible

INFPHD441 Semantic Web applications

6 credits, lecture, obligatory optional, not reproducible

INFPHD444 SAT Solving Algorithms

6 credits, lecture, obligatory optional, not reproducible

INFPHD447 Formal and semi-formal approaches for information security and information architecture

6 credits, lecture, obligatory optional, not reproducible

INFPHD450 Stochastic Models and Adaptive Algorithms

6 credits, lecture, obligatory optional, not reproducible

INFPHD451 Numerical solution of problems in Multibody dynamics

6 credits, lecture, obligatory optional, not reproducible

INFPHD452 Mathematical methods in cryptography

6 credits, lecture, obligatory optional, not reproducible

Complex exam preparatory courses

INFPHD637 Databases and knowledge bases (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD636 Information systems (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD601 Design and analysis of algorithms (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD602 Complexity (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD603 Fourier analysis and its applications (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD604 IT security (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD605 Computer algebra (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD606 Artificial Intelligence (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD607 Numerical computations (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD608 The teaching methodology of Information Technology (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD609 Parallel and Distributed Systems (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD610 Programs correctness and semantics (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD611 Programming methodology (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD612 Programming Languages (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD613 Theoretical Foundations of Computer Science (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD614 Computer Graphics (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD615 Computer Systems (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD616 Data Mining (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD617 Data Structures and Algorithms (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD618 Approximation Theory (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD619 Bioinformatics (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD620 Numerical solution of differential equations (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD621 Numerical solution of the equation system (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD622 Models of computation and their applications (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD623 Fractal geometry, chaos (complex exam preparatory)
6 credits, practice, optional, not reproducible

INFPHD624 Mathematical modelling of Curves and Surfaces (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD625 Information Theory and Coding (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD626 Information systems applications (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD627 Image Processing (Computer Vision) (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD628 Modern databases (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD629 Mathematical Logic (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD630 Neural Computing (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD631 Programming Technology (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD632 Temporal Logic (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD633 Geoinformatics (complex exam preparatory)
6 credits, practice, optional, not reproducible
INFPHD638 Mathematics of networks and the www (complex exam preparatory)
6 credits, practice, optional, not reproducible

Scientific module (obtainable credits: 216 credits, minimum to obtain: 156)

1–4. semester: minimum 66 credits, maximum 96 credits
5–8. semester: minimum 90 credits, maximum 120 credits

INFPHD200 Research work
Minimum 156, maximum 216 credits in 8 semesters, practice, obligatory, reproducible

INFPHD201 Detailed research plan, 1st semester
2 credits, practice, obligatory, not reproducible

INFPHD202 Yearly written report at the end of the 3rd semester
2 credits, practice, obligatory, not reproducible

INFPHD204 Yearly written report at the end of the 8th semester
2 credits, practice, obligatory, not reproducible

Research credits may be given for obtaining abilities and skills necessary for research activities, for progress in the research, for the publication of research results. Recommendation for the specification of research credits (the supervisor acknowledges the research credits in proportion to the amount of invested work).

Recommended credits for the accomplishment of tasks:

- Professional presentation: 2-4 credits
- Presentation at a conference in the home country: 4-5 credits
- Poster at a conference in the home country: 3-4 credits
- Presentation at a conference abroad: 6-10 credits
- Poster at a conference abroad: 4-8 credits
- Publication written in native language: 4-8 credits
- Publication written in foreign language: 8-14 credits

Research without concrete results:
Research without concrete results has to be evaluated in proportion to the invested amount of work (1 credit = 30 working hours), only 20 credits may be given per semester for research without concrete results.

Teaching module (obtainable credits: 45, obligatory credits min: 0)

I**NFPHD300- Teaching**

Minimum 0, maximum 48 credits in 8 semesters, practice, mandatory, reproducible

Credit evaluation of teaching activity: 1 contact hour (45 minutes) equals 2 credits.

Professional credits

I**NFPHD205**

Minimum 0, maximum 24 credits in 5-8 semesters, practice, mandatory, reproducible

Course descriptions (recommended literature):

INFPHD005 Software Quality Management

short description:
It is generally accepted that, in addition to supporting technology, efficient and reliable software development requires mature and well managed processes. Progress in this domain has been considerable during the past years resulting in a need for keeping pace by companies which intend to preserve and improve their competitive positions. Progress is regularly taking place for example with the well-known ISO 9000 standard which had an essentially modified version appearing in year 2000. The first version of CMMI (Capability Maturity Model Integration) also appeared in year 2000 and is a descendent of the original CMM (Capability Maturity Model) which still determines the mental models of professionals. The other major parallel high impact initiative is the trial and adoption of the ISO/IEC 15504 (SPICE~Software Process Improvement and Capability Determination) international standard being recently republished under the ISO/IEC 33000 series. SPICE and CMMI are both the results and further catalysts of the spreading of process maturity models to other disciplines than software development to the extent that the word „software" was finally omitted from the published ISO/IEC 15504 standard making it directly applicable to arbitrary processes.
Software process management has been facing a new challenge with the spread of offshore software development whether in the form of filiales or outsourcing. It is of particular interest in this respect, how knowledge and capability maturity can be transferred to environments with differing cultural backgrounds. Another important issue is the applicability of new approaches in small businesses.
Standards studied: ISO/IEC 25000 SQuaRE (Software Product Quality Requirements and Evaluation); Product and process quality ISO 9000 ; The Capability Maturity Model CMM ; The Capability Maturity Model Integrated CMMI ; Software life cycle processes ISO/IEC 12207 ; Software process improvement and capability determination as defined in ISO/IEC 15504 (SPICE).

literature:

- Miklos Biro (2014): Open Services for Software Process Compliance Engineering. In: Geffert Viliam, Preneel Bart, Rovan Branislav, Štuller Július, Tjoa AMin (ed.), SOFSEM 2014: Theory and Practice of Computer Science. Berlin; Heidelberg; New York: Springer Verlag, 2014. p. 1-6. (Lecture Notes in Computer Science) 18327 ISBN:978-3-319-04297-8), http://link.springer.com/chapter/10.1007%2F978-3-319-04298-5_1.
- Korsaa Morten, Biro Miklos, Messnarz Richard, Johansen Jörn, Vohwinkel Detlef, Nevalainen Risto, Schweigert Tomas (2012): The SPI manifesto and the ECQA SPI manager certification scheme. JOURNAL OF SOFTWARE: EVOLUTION AND PROCESS 24: pp. 525-540. (2012). http://onlinelibrary.wiley.com/doi/10.1002/smr.502/abstract
- Biró, M. (2009): The Software Process Improvement Hype Cycle. Invited contribution to the Monograph: Experiences and Advances in Software Quality (Guest editors: D.Dalcher, L. Fernández-Sanz) CEPIS UPGRADE Vol. X (5) (2009) pp. 14-20. http://www.cepis.org/files/cepisupgrade/issue%20V-2009-fullissue.pdf
- Biró M, Messnarz R, Davison AG (2002): The Impact of National Cultural Factors on the Effectiveness of Process Improvement Methods: The Third Dimension, SOFWARE QUALITY PROFESSIONAL (ASQ~American Society for Quality) 4: (4) pp. 34-41. http://www.asq.org/pub/sqp/past/vol4_issue4/biro.html

- Biró, M; Messnarz, R. (2000): Key Success Factors for Business Based Improvement. Software Quality Professional (ASQ~American Society for Quality) Vol.2, Issue 2 (March 2000). http://www.asq.org/pub/sqp/past/vol2_issue2/biro.html
- Biró,M.; Tully,C (1999): The Software Process in the Context of Business Goals and Performance. Chapter in the book entitled Better Software Practice for Business Benefit (ed. by R. Messnarz, C. Tully). (IEEE Computer Society Press, Washington, Brussels, Tokyo, 1999) (ISBN:0-7695-0049-8). http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0769500498.html

INFPHD008 Search and communication complexity, Seminar
precondition: Elementary combinatorics and probability theory
type of examination: oral

short description:
The basic problems of Search Theory is the following. An unknown element of a finite set is sought by questions asking if the unknown element is in a certain subset or not. The mathematical problem is to minimize the number of questions needed to find the unknown element, under different conditions on the questions. The area has important application (among others) in bioinformatics. The basic problem of Communicational Complexity: two participants need to determine the value of a given function of two variables where both participants know only the value of their own respective variables. One has to minimize the amount of information transferred between the partners.. The mathematical background of the two areas are very similar. The goal of the seminar is to follow the literature, the participants read new papers.

literature:
- M. Aigner: Combinatorial Search, Teubner, 1988.
- E. Kushelevity, N. Nisan: Communicational Complexity, Cambridge University Press, 1997.

INFPHD009 Computer aided surface reconstruction
type of examination: oral

short description:
The subject discusses the computer representations of objects in computer graphics, animation, engineering design, medical image processing, and their construction from discrete measured data. Main topics are:

Methods, devices and technics of data collection of surfaces.
Pre-processing of measured data, noise elimination.
Decimation, triangulation of point sets, STL data structure.
Segmentation of point sets.
Fitting of simple surfaces, planes, cylinders, cones, spheres.
Fitting of free form surfaces, parametrizations, functionals, accuracy, smoothness.
Fitting with constraints.
Composition of geometry and topology of CAD models.
Applications of surface reconstruction in technics, medicine, art.

literature:
- Handbook of Computer Aided Geometric Design, Ed. by G. Farin, J. Hoschek. M.S. Kim, Elsevier, (2002)

INFPHD015 Research topics of autonomous systems

short description:
In current research trends indicate the need for a networked infrastructure in which open software components achieve business goals by cooperating flexibly with each other, dynamically adapting themselves to the changing environment, with minimal human intervention and in accordance with the aims of their users and their organisations. Although there is no uniquely established technology for this, there are many initiatives containing elements pointing towards this aim. In this course the students will get acquainted with these technology elements and investigate their convergence.
Introduction: requirements, technologies, market trends. Intelligent agents, agents and object orientation, agents and expert systems, agent architectures. Multi-agent interactions, utility and preference, strategy. Reaching agreements, mechanism design, auction, negotiation, argumentation. Communication, speech act, agent communication language, ontology. Cooperation, distributed problem solving, task and result sharing,

inconsistency, coordination, synchronisation. Evaluation: reliability, reputation, monitoring. Web services: protocols, service descriptions, finding services, interoperability. Applications: business process management, logging and monitoring, self healing and optimisation, semantic web services, reliability and reputation.

literature:

- An Introduction to MultiAgent Systems / Michael Wooldridge / ISBN: 0-471-49691-X / 366 Pages / April 2002 /
- http://www.wiley.com/cda/product/0,,047149691X,00.html

INFPHD021 Advanced database systems I. (Fundamentals of Databases I-II.)

precondition Basics of databases
type of examination oral

short description:
Part I.: Relational query languages: The relational model;
Conjunctive queries (rule based, tableau queries, conjunctive calculus, SPC/SPJR Algebra)
Adding Negation: Non recursive Datalog, Algebra, relational (domain) calculus, equivalence theorems
Query optimization, equivalence and containment of tableau queries, undecidability of query equivalence, acyclic joins
Part II. Dependency theory
Functional and Key dependencies:
Definition, implication problem, algorithm for determining implication, Armstrong axioms.
Join and multivalued dependencies, decompositions. Axiomatizations: yes for FD and MVD; no for FD and JD.
The Chase algorithm. Equivalence of tableau queries under dependencies. The Chase and the impolication.
Inclusion dependencies, implication, axiomatization, complexity.
Inclusion dependencies and FD-s: undicadability theorem.
Axiomatization, decidability of implication, finite and unrestricted interpretations, general tableau dependencies.

literature:

- Abiteboul S. –Hull R.– Vianu V.: Foundation of Databases, Addison-Wesley Publ. Comp. 1995., A-C chapters.
- Ullman J.D., Widom J. : A First Course in Database Systems, Pearson Prentice Hall, 2008.

INFPHD022 **Advanced database systems II. (**Fundamentals of Databases II-III.)

precondition Basics of databases
type of examination oral

short description:
Part I.: Relational query languages: The relational model;
Conjunctive queries (rule based, tableau queries, conjunctive calculus, SPC/SPJR Algebra)
Adding Negation: Non recursive Datalog, Algebra, relational (domain) calculus, equivalence theorems
Query optimization, equivalence and containment of tableau queries, undecidability of query equivalence, acyclic joins
Part II. Dependency theory
Functional and Key dependencies:
Definition, implication problem, algorithm for determining implication, Armstrong axioms.
Join and multivalued dependencies, decompositions. Axiomatizations: yes for FD and MVD; no for FD and JD.
The Chase algorithm. Equivalence of tableau queries under dependencies. The Chase and the impolication.
Inclusion dependencies, implication, axiomatization, complexity.
Inclusion dependencies and FD-s: undicadability theorem.
Axiomatization, decidability of implication, finite and unrestricted interpretations, general tableau dependencies.

literature:

- Abiteboul S. –Hull R.– Vianu V.: Foundation of Databases, Addison-Wesley Publ. Comp. 1995. A-C chapters.
- Ullman J.D., Widom J. : A First Course in Database Sytems, Pearson Prentice Hall, 2008.

INFPHD023 Data Mining
type of examination: written

short description:
The task of data mining: Knowledge discovery and applications of data mining.
Data warehouses , OLAP data, OLAP operations of multi-dimensional data model.
Data preprocessing, data cleaning, data integration transformation, reduction.
Discretization, conceptual hierarchies.
Data mining models, general characteristics, association (association) rules, clustering, decision trees, classification, prediction , neural networks, regression.
General and special, advanced data mining technologies (web mining, graph mining)
Data mining tools

literature:
- Anand Rajaraman, Jure Leskovec, Jeffrey D. Ullman: Mining of Massive Datasets, Cambridge University Press, 2014 http://i.stanford.edu/~ullman/mmds/book.pdf
- Jiawei Han and Micheline Kamber, Data Mining: Concepts and Techniques, 3rd edition, Morgan Kaufmann, 2011. http://www.cs.uiuc.edu/~hanj/bk3/
- Stanford University Course: CS246: Mining Massive Datasets http://www.stanford.edu/class/cs246/

INFPHD032 Type theory
short description:
(Dependent) type theory is a programming language in which the type of a program can be seen as a mathematical proposition and a program can be seen as the proof of the corresponding type. In this research seminar we study the syntax and semantics of dependent type theory in two ways: (1) abstractly, using the language of category theory, (2) using Agda which is an implementation of type theory. We discuss the following topics:

* basic category theory
* Categories with Families (CwF), as a notion of model of type theory
* the syntax as an initial model
* inductive types, higher inductive types
* coinduction
* identity type
* intensional, extensional and homotopy type theory
* different models of type theory: set, graph, reflexive graph, setoid, presheaf, simplicial, cubical
* parametricity, definable functions
* proof of normalisation using logical predicates

Literature:

- Martin Hofmann. Syntax and Semantics of Dependent Types. In: Semantics and Logics of Computation, 1997, Cambridge University Press. pp. 79-130.
- Univalent Foundations Project. Homotopy Type Theory – Univalent Foundations of Mathematics. Technical report, Institute for Advanced Study, 2013
- Altenkirch Thorsten, Ambrus Kaposi. Type theory in type theory using quotient inductive types. In: Rastislav Bodík, Rupak Majumdar (ed.) Proceedings of the 43rd Annual ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages, POPL 2016, St. Petersburg, FL, USA, January 20 - 22, 2016. Konferencia helye, ideje: St. Petersburg, United States of America, 20/01/2016-22/01/2016. New York: ACM Press, 2016. pp. 18-29.
- Thorsten Altenkirch, Ambrus Kaposi. Normalisation by Evaluation for Dependent Types. In: Delia Kesner, Brigitte Pientka (ed.) 1st International Conference on Formal Structures for Computation and Deduction. Konferencia helye, ideje: Porto, Portugal, 22/06/2016-26/06/2016. Saarbrücken: Schloss Dagstuhl Leibniz-Zentrum für Informatik, 2016. Paper 6.

INFPHD034 Analysis of Algorithms and Data Structures I.

short description:
THEORETICAL BASIS OF COMPLEXITY ANALYSIS
Recurrence equations for running time. Trees of recursive calls. Iterative solution method. The master method, the master theorem. Generator functions. Amortized analysis. The accounting and the potential method.

BALANCED SEARCH TREES (advanced)
Red-black trees, insertion and deletion, rotations. Splay trees, self-adjusting mechanism.

ADVANCED DATA STRUCTURES
Binomial heaps, built up from binomial trees, representation, operations, amortized running time.
Fibonacci heaps, representations, amortized running time analysis.
Disjoint set data structure, in Kruskal's algorithm, linked list implementation, rank properties, union find.

SPECIAL ISSUES
Students may independently choose special issues suitable to their PhD research. An assay and a presentation can be accepted as part of the fulfilment of the course.

Literature:
- T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein: Algoritthms. MIT Press, 2003.
- E. Horovitz, S. Sahni, S. Rajasekaran: Computer Algorithms. Computer Science Press, 1998.
- M. Attalah (Ed.): Handbook of Algorithms and Computation, CRC Press, 1999.

INFPHD035 Comparative analysis of Programming Languages
type of examination: oral

short description:
Introduction
Language Design
Lexical elements
Control structures, statements
Data types (built-in, composite)
Subprograms
Exception handling
Abstract data types
Object-oriented programming
Type parameters, generic
Correctness in practice
Concurrency

literature:
- SEBESTA, Robert W., *Concepts of programming languages*, Edinburgh, Pearson, 2013, ISBN 978-0-273-76910-1
- MEYER, Bertrand, *Object-oriented software construction*, Upper Saddle River, Prentice Hall, 1997, ISBN 0-13-629155-4
- NYÉKYNÉ GAIZLER Judit et al. (ed.), *Advanced Programming Languages*, Budapest, ELTE, 2014, ISBN 978-963-284-450-3
- SCOTT, Michael L., *Programming Language Pragmatics*, Amsterdam, Morgan Kaufmann, 2009, ISBN 978-0-12-374514-9

INFPHD037 Artificial Neural Nets
type of examination: oral exam

short description:
The course is dealing with relevant problems for artificial neural nets (ANNs). We start from considerations on the statistics of natural phenomena and restrict most of our attentions to methods that can deal with heavy-tailed statistics. In particular, we treat over-complete and sparse representations. We also consider the homunculus fallacy and emphasize the relevance of generative reconstruction networks with particular attention on predictive

networks. We show the interconnections between sparse coding, support vector machines and independent component analysis.

literature:

- András Lőrincz: Learning Systems I (1997)
- Simon O. Haykin: Neural Networks and Learning Machines, 3rd Edition (2008)
- Emmanuel J. Candès, Xiaodong Li, Yi Ma, and John Wright. Robust principal component analysis? *Journal of the ACM (JACM)* 58, no. 3 (2011)
- András Lőrincz and Szabó Zoltán: Machine Recommendations and Machine Decision Making (2013)

INFPHD042 Introduction to Computer Algebra

Short description:
Computer systems with the ability to handle symbolic computations are called computer algebra systems.
They are able to perform error-free computations with arbitrary precision. These systems are indispensable in modern science and practice. In this course we show how these systems work and how can they be used in mathematical modelling.

Common topics: Maple, Sage, Mathematica. Data representation, structures, programming, I/O, packages.
Special topics: Polynomials, roots, GCD computations, Gröbner basis, number theoretical problems, basic problems in cryptography, error-correcting codes.

literature:

- Maple, Mathematica, Sage Manuals
- Heck, A, *Introduction to Maple,* 3rd edition, Springer-Verlag, New York, 2003, ISBN 0-387-00230-8
- Wolfram, S, *Mathematica. Wolfram Media;* Fifth edition (August 22, 2003), ISBN-10: 1579550223
- Von zur Gathen, Gerhard: *Modern Computer Algebra,* Cambridge, 2003, ISBN-10: 0521641764
- Geddes et al: *Algorithms for Computer Algebra,* Springer, 2003, ISBN-10: 0792392590
- Kovács, A, *Computer Algebra: Impact and Perspectives*. Nieuw Archief voor Wiskunde **17**/1, 1999, 29-55.

INFPHD048 Analysis of Algorithms and Data Structures II.

Short description:
ALGORITHM DESIGN METHODS

- Divide and conquer method, recursion, recursive algorithms (e. g. binary search, quick sort, merge sort, k^{th} element selection)
- Greedy algorithms, greedy-choice property, optimal substructures, matroids (e. g. algorithms of Dijkstra, Prim, Kruskal, the knapsack problem, Huffman code)
- Dynamic programming method (e. g. activity selection, Floyd-Warshall algorithm for all-pairs shortest paths)
- Backtracking search (e. g. 8-queens problem, the 15 tiles puzzle, other problems of artificial intelligence) backtracking vs. depth search graph algorithm
- Branch and bound, heuristic graph search algorithms
- Random algorithms, generating random numbers, methods of analysis (e. g. quick sort, randomly built search trees, selection of the k^{th} element, checking polynomial identities, existence of perfect matching in bipartite graphs)
- Approximate algorithms (e. g. minimum edge cover set, respectively vertex cover set in graphs, Euclidean travelling salesman, partial sum problem in polynomial time)

SPECIAL ISSUES
Students may independently choose special issues suitable to their PhD research. An assay and a presentation can be accepted as part of the fulfilment of the course.

Literature:

- T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein: Algorithms. MIT Press, 2003.
- E. Horovitz, S. Sahni, S. Rajasekaran: Computer Algorithms. Computer Science Press, 1998.
- M. Attalah (Ed.): Handbook of Algorithms and Computation, CRC Press, 1999.

INFPHD052 Queueing theory

type of examination: oral

short description:
One gives an introduction to the main topics of queueing theory including the classical Erlang-type systems and the more general queueing models, to the methods and tools developed for their investigation. There are considered some latest results connected with telecommunication systems.

literature:

- Kleinrock, L., Queueing systems, John Wiley and Sons, 1975.
- Lakatos,L., Szeidl,L. and Telek,M., Introduction to queueing systems with telecommunication applications, Springer, 2013.

INFPHD061 Research methodology
type of examination: Doctoral colloquium

Short description:
Exploring different research methods and applying them to different research problems
Themes:
Basics of Research
Qualitative Research
Quantitative data analysis
Conversation Analysis & Developmental research
Experimental Research
Research in Education
Early Childhood Research

Literature:

- (ed.) David H. Jonassen (2004), Handbook of Research on Educational Communications and Technology, Association for Educational Communications and Technology, Lawrence Erlbaum Associates.
- John W. Best, James V. Kahn, (2003) *Research in Education*, Pearson Education Inc.
- Glenda Mac Naughton, Sharane A. Rolfe, Iram Siraj-Blatchford (2001), Doing Early Childhood Research: International Perspectives on Theory and Practice, Open University Press

INFPHD073 Extremal Set Theory Seminar

precondition: Elementary combinatorics
type of examination: oral

short description:
We are looking for the maximum number of subsets of an n-element set. A typical example is the theorem of Sperner that determined the maximum number of subsets without inclusion. The goal of the seminar is to follow the newest results of the theory.

literature:

- Konrad Engel: Sperner Theory, Cambridge University Press, 1997.

INFPHD078 Cryptology Seminar

precondition: Elementary combinatorics, probability theory, abstract algebra, complexity theory
type of examination: oral

short description:
The participants of the seminar study the new results of the area. The subjects are, among others, authentication and identification methods (digital watermark, digital fingerprint), computation with several participants, election systems, auctions in the web.

literature:
- Colin Boyd, Anish Mathuria: Protocols for authentication and key establishement, Springer, 2003.
- Jozef Pieprzyk, Thomas Hardjono, Jennifer Seberry: Fundamentals of computer security, Springer, 2003.
- Alfred J. Menezes, Paul C. van Oorschot, Scott A. Vanstone : Handbook of applied cryptography, CRC Press, 1997.
- New literature: http://eprint.iacr.org

INFPHD080 Systems of language processors: formal –language-theoretic models of multi-agent systems

precondition: basic knowledge in formal language and automata theory and in distributed computing
type of examination: oral

Short description:
The theory of multi-agent systems is in the focus of interest in contemporary distributed and decentralized computing. It has particular importance in artificial intelligence, nature-motivated computation, natural language processing, only to mention a few. The course is devoted to formal descriptions of properties and behaviour of multi-agent systems, especially to their formal- language- theoretic models, called grammar systems or systems of language processors.

Topics to be discussed:
Cooperating/distributed grammar systems, syntactic models of the well-known blackboard model of problem solving, where the cooperating problem solving agents are represented by language processors (grammars). T he actual problem to be solved and stored in the common database, the blackboard, is given by strings jointly generated by the grammars, and the obtained language represents the problem solution. During the course, important variants of the basic model, cooperation strategies, complexity questions are discussed.

Colonies: collections of very simple, purely reactive agents. Descriptions of their behaviour with formal-language -theoretic tools.

Eco-grammar systems: Formal language-theoretic models of artificial life. Descriptions of dynamically varying, developing, adaptive agents and their shared, changing environment. Interactions between the agent collections and their environments.

Networks of language processors: networks of formal rewriting systems communicating strings or multisets of strings. Communication strategies, computational-, descriptional, and communication complexity. Phenomena in these networks.
Representation of well-known types of networks in terms of networks of language processors.

Literature:
- E. Csuhaj-Varjú, J. Dassow, J. Kelemen, Gh. Paun: Grammar Systems: A Grammatical Approach to Distribution and Cooperation. Gordon and Breach Science Publishers, Yverdon, 1994.
- J. Dassow, Gh. Paun, G. Rozenberg: Grammar Systems. In: Handbook of Formal Languages. (G. Rozenberg, A. Salomaa, eds.), Vol 2, Chapter 4, Springer, 1997.
- E. Csuhaj-Varjú: Grammar Systems. In: Formal Languages and Applications. Studies in Fuzziness and Soft Computing 148. (C. Martín-Vide, V. Mitrana, Gh. Paun, eds.), Springer, Berlin, 2004, 275-310.
- Multiagent Systems. A Modern Approach to Distributed Artificial Intelligence. (G. Weiss, ed.), The MIT Press, Cambridge, Massachusetts, 1999.
- Michael Wooldridge: An Introduction to MultiAgent Systems, John Wiley & Sons Ltd, 2002.
- José M. Vidal: Fundamentals of Multiagent Systems: with NetLogo Examples
- (http://multiagent.com/2008/12/fundamentals-of-multiagent-systems.html)
- Recent literature.

INFPHD102 Bio-inspired computing: Membrane Systems
precondition: basic knowledge in theoretical computer science
type of examination: oral

Short description:
Bio-inspired computation is research area on the borderline of computer science, molecular biology, and chemistry. One of its most important, rapidly evolving subfield is membrane computing, a theory has been launched by Gheorghe Paun in 1998. Membrane systems, or P systems, are distributed and parallel computing devices inspired by functioning and architecture of living cells. The main ingredient of a P system is a hierarchically embedded structure of membranes.
Each membrane encloses a region that contains multisets of objects and might also contain other membranes. There are
rules associated to the regions describing the evolution of the objects present in the membranes and their communication
between the neighbouring regions. The evolution of the system corresponds to a computation.

The theory of P systems provides unconventional, among them several computationally complete (equivalent in power to Turing machines), models both for computing and for describing natural processes and phenomena.

The aim of course is to introduce generic P systems and their properties, in particular, their computational power, computational-, and descriptional complexity. More sophisticated variants, as membrane systems with dynamically varying structure and functioning, tissue-like P systems, spiking neural P systems, P automata, etc. and recent developments are also discussed; some applications of the theory in computer science are demonstrated.

Literature:
- Gh. Paun: Membrane Computing. An Introduction. Springer-Verlag, Berlin, 2002.
- G. Ciobanu, Gh. Paun, M.J. Pérez-Jiménez, eds, Applications of Membrane Computing. Springer-Verlag, Berlin, 2005
- Gh. Paun, G. Rozenberg, A. Salomaa (eds.): The Oxford Handbook of Membrane Computing. Oxford University Press, Oxford, 2010
- P systems webpage: (http://ppage.psystems.eu)

INFPHD128 Research Areas of Generative Programming
type of examination: oral

short description:
Generative programming is a relatively new programming paradigm became popular in the last decade. As new paradigms, do not replace but rather extend extending technologies, generative programming based on code generation and code transformation extends object-oriented and functional paradigms. During this course students will understand the foundation of generative programming including the design aspects, programming language tools and libraries. They learn the possible application fields, and how they have to choose and apply the right methods.

Course outline: The definition of generative programming and its typical application areas. Relationship between generative programming and the object-oriented and functional programming paradigms. Overview of generative programming: generic programming, feature oriented programming. C++ templates, template metaprogramming and its libraries: Loki, Boost. Aspect-oriented design and programming, AspectJ. Generic programming in functional languages. Intentional programming. Multi-staged languages.

literature:
- Krzysztof Czarnecki, Ulrich Eisenecker: Generative Programming: Methods, Tools, and Applications Addison-Wesley, 2000, ISBN: 0201309777
- Andrei Alexandrescu: Modern C++ Design: Generic Programming and Design Patterns Applied Addison Wesley, 2001, ISBN: 0201704315
- David Abrahams, Aleksey Gurtovoy: C++ Template Metaprogramming : Concepts, Tools, and Techniques from Boost and Beyond (C++ in Depth Series)Addison-Wesley, 2005, ISBN: 0321227255
- Björn Karlsson: Beyond the C++ Standard Library Addison-Wesley, 2005. ISBN: 0-321-13354-4
- Ivan Kiselev: Aspect-Oriented Programming with AspectJ SAMS, 2003. ISBN 0-672-32410-5

INFPHD142 M-Learning (Mobile Learning)

type of examination: Doctoral colloquium

Short description:
Exploring the Theories underlining Mobile Learning, technological trends and innovations that support developments.

Literature:
- NMC Horizon Reports http://www.nmc.org/horizon-project/horizon-reports
- Mobile Learning Org http://www.mlearning-conf.org/
- International Association for Mobile Learning http://www.iamlearn.org/
- International Journal of Mobile Learning and Association http://www.inderscience.com/jhome.php?jcode=ijmlo
- UNESCO resources http://www.unesco.org/new/en/unesco/themes/icts/m4ed/mobile-learning-resources/
- Sharples M., The Theory of Learning in the Mobile Age, Springer 2010 http://link.springer.com/chapter/10.1007/978-3-531-92133-4_6#page-1
- Sharples M., Big Issues in Mobile Learning Report of a workshop by the Kaleidoscope Network of Excellence Mobile Learning Initiative (2006)
- Schoonenboom J., Goita Y., Montandon L., Keenoy K., Levene M., Faure D., David J., Turcsanyi-Szabo M., Kaszás P., Pluhár Z., Jones A., Blake C., Lejeune A., Trails of Digital and Non-Digital LOs EU Sixth Framework programme priority 2, Information society technology, Network of Excellence Kaleidoscope, (contract NoE IST-507838), project TRAILS: Personalised and Collaborative Trails of Digital and Non-Digital Learning Objects. (2004)
- Sharples M., Taylor J., Vavoula G., A Theory of Learning for the Mobile Age in The Handbook of Elearning Research. (2006) Not yet available
- Kondor Z., Being Mobile: Cognitive Multiplicity in Mobile Understanding. The Epistemology of Ubiquitous Communication (2006) 79-90

INFPHD143 Methods for Teaching Informatics

Short description:
Teaching methods for the specific fields of Informatics: how to build the curriculum on a specific method; which competences and key competences are developed in such a curriculum; on which level and in which form can a specific method be used most efficiently…
The methods cover the following fields: programming (the presentation and analysis of 9 methods, with case studies), programming languages (the presentation and analysis of 6 methods, with case studies), and application systems (the presentation and analysis of 5 methods, with case studies). The different methods are independently examined and then compared.
Hardware-software teaching methods.
The forms of evaluation in Informatics: which competences and skills can be measured with a specific form of evaluation; how effective is a specific form of evaluation… The practice of evaluation (schools, maturity exam, OKTV, ECDL, OKJ). The comparative analysis of maturity exams.
The comparative analysis of talent management types. The presentation of materials in support of the teaching methods.
The project method in the education of Informatics.

INFPHD156 R&D questions of innovative TEL (Technology Enchanced Learning)
type of examination: Doctoral colloquium

Short description:
Exploring Instructional Design Theories and their possible situated application achieving Technology Enhanced Learning.

Themes:
Instructional-Design Theories and Models
A New Paradigm of Instructional Theory
Fostering Cognitive, affective and Psychometric Development
Future Research

Literature:

- NMC Horizon Reports http://www.nmc.org/horizon-project/horizon-reports
- Peter Goodyear: Technology Enhanced Learning - Design Patterns and Pattern Languages, Sense Publishing 2012 https://www.sensepublishers.com/media/1037-technology-enhanced-learning.pdf
- Technology Enhanced Learning. Quality of Teaching and Educational Reform, Springer 2010 http://link.springer.com/book/10.1007/978-3-642-13166-0
- Ed Juliet Sprake : Learning -Through -Touring, Springer 2010 http://link.springer.com/book/10.1007/978-94-6091-777-6
- Ed. Charles M. Reigeluth, Instructional-Design Theories and Models Volume II – A New Paradigm of Instructional Theory, Lawrence Erlbaum Associates, 1999
- (ed.) Andrew Brown & Niki Davis, (2004) World Yearbook of Education 2004 – Digital technology, communities and education, RoutledgeFalmer.
- (ed.) David H. Jonassen (2004), Handbook of Research on Educational Communications and Technology, Association for Educational Communications and Technology, Lawrence Erlbaum Associates.

INFPHD157 Search and communication complexity, Seminar, II
precondition: Elementary combinatorics and probability theory
type of examination: oral

short description:
The basic problems of Search Theory is the following. An unknown element of a finite set is sought by questions asking if the unknown element is in a certain subset or not. The mathematical problem is to minimize the number of questions needed to find the unknown element, under different conditions on the questions. The area has important application (among others) in bioinformatics. The basic problem of Communicational Complexity: two participants need to determine the value of a given function of two variables where both participants know only the value of their own respective variables. One has to minimize the amount of information transferred between the partners.. The mathematical background of the two areas are very similar. The goal of the seminar is to follow the literature, the participants read new papers.

literature:

- M. Aigner: Combinatorial Search, Teubner, 1988.
- E. Kushelevity, N. Nisan: Communicational Complexity, Cambridge University Press, 1997.

INFPHD158 Search and communication complexity, Seminar, III
precondition: Elementary combinatorics and probability theory
type of examination: oral

short description:
The basic problems of Search Theory is the following. An unknown element of a finite set is sought by questions asking if the unknown element is in a certain subset or not. The mathematical problem is to minimize the number of questions needed to find the unknown element, under different conditions on the questions. The area has important application (among others) in bioinformatics. The basic problem of Communicational Complexity: two participants need to determine the value of a given function of two variables where both participants know only the value of their own respective variables. One has to minmize the amount of information transferred between the partners.. The mathematical background of the two areas are very similar. The goal of the seminar is to follow the literature, the participants read new papers.

literature:

- M. Aigner: Combinatorial Search, Teubner, 1988.
- E. Kushelevity, N. Nisan: Communicational Complexity, Cambridge University Press, 1997.

INFPHD160 Curriculum Theory of Public Education Informatics

Short description:
Curriculum Theory: the types of curricula in Informatics, the trends of curriculum development, the main types of curriculum management, the planning of student activities and tool systems, the implementation and assessment of curricula and training programs. The main tendencies in the development of the European and Hungarian curriculum in Informatics.

The systematic model of content regulation in public education. The two-level curriculum regulation in present-day Hungarian practice: the National Curriculum (NAT), the frame curricula, and the local curricula.
The National Curriculum (NAT) and its recent correction. Key competences and frame curriculum competences. Curriculum theory and its application in IT curriculum development.
The main factors of elaborating and developing curricula in Informatics. The analysis of frame curricula, school curricula, educational tools available in schools, program packages, exam requirements. The correspondences between curricula and materials in Informatics. Studies from the issue of curriculum development.
The comparative examination of the central and the local curriculum development in Informatics. The comparative examination of some national and some international curriculum regulation models.
Case studies and result analyses in the topics of curriculum-making, curriculum-development, and content regulation in public education Informatics.
The main phases of the Hungarian education of Informatics, from the perspective of curriculum development.
Study groups and specialization in Informatics. The role of the Internet in teaching Informatics. Alternative educational concepts and experiements.

INFPHD167 Nonlinear phenomenon on lattice
type of examination: lecture

Short description:
The subject offers new information for those students who want to learn the determination of theoretical and experimental results using lattice models.

We introduce the lattice calculations which are used in the natural sciences and the application of nonlinear models. Dynamical systems are formulated by discrete lattice field theory. We discuss the numerical methods which are used to determine the theoretical values, respectively measurable quantities. The chaotic dynamics of Yang-Mills equations is characterized by the full Lyapunov spectrum.

Themes:
- Motivation
-Introduction to the basic concepts of lattice counting (Discretization of the continuous scalar and vector field)
- Dynamical Systems: Chaos, Lyapunov exponents, bifurcation, limit cycles, strange attractors, Kolmogorov-Sinai entropy concept and their numerical determination
- Dynamic systems on lattice, (XY) model
- Introduction of Nonabelian field theory
- Concept of lattice field theory
- Definition of the quantities which are used in these models (expectation value, standard deviation).
- Numerical methods: Monte Carlo method, Metropolis method, Langevin algorithm and Heat-Bath process
- The reliability of calculated values, correction of lattice error
- Comparison of results which are derived from different model calculation (perturbative or nonperturbative procedures)
-Determination of the full spectrum of Lyapunov exponent on the lattice Yang-Mills theory

literature:

- Montvay I., *Quantum Field on a Lattice*, Cambridge Monographs on Mathematical Physics, Cambridge Univ. Press, (1994)
- M. Creutz, *Quark, gluons and lattices*, Cambridge University Press, (1983),
- Fülöp Á., *Nemlineáris jelenségek numerikus meghatározása*, Doktori értekezés (2006),
- Steven Weinberg, *The Quantum Theory of Fields*, Cambridge University Press, (1998).

INFPHD179 Informatics Research Methodology 1 – Research Seminar

Requirement: independent analysis of the set studies and articles, independent curriculum development in the subject's topic and its presentation and defense in class.

Short description:
Formation of concrete subject-related task sheets
A: How can you use a task to create further tasks? How much can the solution of the new tasks be similar to the original? How can you make up a new task by changing the solution?
B: How can you build your curriculum on one task?

C: How can you make and assign an evaluation system to a given curriculum so it covers all the relevant parts?
D: How can you weigh the specific parts of the evaluation system? Is it a problem if a certain sub-knowledge is tested several times?
E: How can you analyze tasks, identify similarities, and construct tasks similar to a given type?

INFPHD181 Computer Vision
type of examination: oral exam

short description:
Basics of projective geometry, camera models, camera calibration
Scale-space, invariant local features
Robust parameter estimation, outlier detection, RANSAC
Stereo vision, correspondence, ep[ipolar geometry, fundamental matrix, rectification, dense matching, triangulation, reconstruction
Shape-from-shading, photometric stereo, shape-from-texture, visual hull, structured light
3D point cloud registration, ICP algorithm, robust registration
3D motion analysis, Structure-from-Motion, Tomasi-Kanade factorisation

literature:
M.Sonka, V.Hlavac, R.Boyle, “Image Processing, Analysis and Machine Vision”, Thomson
R.Hartley, A.Zisserman, “Multiple View Geometry in Computer Vision”, Cambridge University Press
Y. Ma, S. Soatto, J. Kosecka, S. Shankar Sastry: “An Invitation to 3-D”, Vision Springer
D.A. Forsyth, J. Ponce, "Computer Vision: A Modern Approach", Prentice Hall
E.Trucco, A.Verri, “Introductory Techniques for 3-D Computer Vision”, Prentice Hall

INFPHD182 Artificial intelligence techniques in robotics
Precondition: Artificial Intelligence, Robotics
type of examination: Oral

short description:
Controlling mobile robots and autonom vehicles in a real world environment is still a challenge. Some of these problems can be solved by using artificial intelligence techniques.
The objective of this subject is to provide students artificial intelligence techniques, methods, which help robots to localise themselves, to create a map of their environment, to cooperate with other robots, and to learn efficiently.

draft syllabus:
- application of the artificial intelligence in the field of robotics,
- navigation, mapping, "Simultaneous Localization And Mapping" (SLAM) algorithms,
- multi-agent, multi-robot systems, swarm intelligence,
- learning in complex and dynamic environment,
- robot behaviour verification using formal proofs

literature:

- FastSLAM: A Factored Solution to the Simultaneous Localization and Mapping Problem with Unknown Data Association
- M. Montemerlo doctoral dissertation, tech. report CMU-RI-TR-03-28, Robotics Institute, Carnegie Mellon University, July, 2003.
- Michael Wooldridge, An Introduction to MultiAgent Systems, John Wiley & Sons Ltd, 2002, paperback, 366 pages, ISBN 0-471-49691-X.
- Gerhard Weiss, ed. by, Multiagent Systems, A Modern Approach to Distributed Artificial Intelligence, MIT Press, 1999, ISBN 0-262-23203-0
- Leonard, John J.; Durrant-Whyte, Hugh F. (1991). "Simultaneous map building and localization for an autonomous mobile robot". Proc. IEEE Int. Workshop on Intelligent Robots and Systems: 1442-1447.
- An Atlas Framework for Scalable Mapping, Michael Bosse, Paul Newman, John Leonard, Martin Soika, Wendelin Feiten, Seth Teller, International Conference on Robotics and Automation, Taipei, Taiwan, September 2003, pp. 1899-1906
- Lynne E. Parker, Frank E. Schneider, Alan C. Schultz : Multi – Robot Multi-Robot Systems. From Swarms to Intelligent Automata, Volume III: Proceedings from the 2005 International Workshop on Multi-Robot Systems, Springer, ISBN-10: 1402033885

- Vito Trianni, Christos Ampatzis, Anders Lyhne Christensen, Elio Tuci, Marco Dorigo, Stefano Nolfi: From Solitary to Collective Behaviours: Decision Making and Cooperation. ECAL 2007: 575-584

INFPHD184 Informatics Research Methodology 2 – Research Seminar

Requirement: independent analysis of the set studies and articles, independent curriculum development in the subject's topic and its presentation and defense in class.

Short description:
Formation of concrete subject-related task sheets
A: How can you use a task to create further tasks? How much can the solution of the new tasks be similar to the original? How can you make up a new task by changing the solution?
B: How can you build your curriculum on one task?
C: How can you make and assign an evaluation system to a given curriculum so it covers all the relevant parts?
D: How can you weigh the specific parts of the evaluation system? Is it a problem if a certain sub-knowledge is tested several times?
E: How can you analyze tasks, identify similarities, and construct tasks similar to a given type?

INFPHD185 Informatics Research Methodology 3 – Research Seminar

Requirement: independent analysis of the set studies and articles, independent curriculum development in the subject's topic and its presentation and defense in class.

Short description:
Formation of concrete subject-related task sheets
A: How can you use a task to create further tasks? How much can the solution of the new tasks be similar to the original? How can you make up a new task by changing the solution?
B: How can you build your curriculum on one task?
C: How can you make and assign an evaluation system to a given curriculum so it covers all the relevant parts?
D: How can you weigh the specific parts of the evaluation system? Is it a problem if a certain sub-knowledge is tested several times?
E: How can you analyze tasks, identify similarities, and construct tasks similar to a given type?

INFPHD187 Dynamical systems with applications using computer algebra

Topics
1. A short introduction to *computer algebra system*s (MAPLE, MATHEMATICA, MATLAB)
2. A short introduction to ordinary differential equations (solution methods, existence and uniqueness)
3. Stability properties of equilibrium points in nonlinear systems
4. Bifurcations of nonlinear systems (saddle-node bifurcation, pitchfork bifurcation, exchange of stability, Hopf-bifurcation)
5. Discrete dynamical systems (solutions, stability and bifurcations)

INFPHD190 Educational Programming Languages – Research Seminar

Short description:
The relevance of the first programming language, the aspects of its selection, and its influence on the programming style.
The analysis, comparison, and development of educational programming languages. The aspects of choosing a programming language. Programming languages as thought shapers.
Using the educational evaluation criteria presented at the lectures, students elaborate on a programming language proposed for educational purposes, identifying the target group (age, interest, etc.), determining how much it matches the methodological criteria of the given target group, and proposing changes to make the given programming language optimal for the target group.
At the end of the research seminar, students submit an endterm paper with the assessment of a chosen programming language and defend it in class.

INFPHD196 Models of Operations Research
type of examination: written exam

short description:
Understanding real-life operations research problems, building the mathematical models, solving the resulting mathematical programming problems, interpreting the solutions. Topics include, but not limited to: finance, telecommunication, logistics, production management and environmental management.

literature:

- Operations Research Models and Methods (John Wiley and Sons, 2003)

INFPHD197 Multiple Objective Optimization
type of examination: Written exam

short description:
Pareto optimality. Non-preference methods. Posteriori methods. Weighting methods. The epsilon constraint method.
A priori methods. Value function. Interactive methods. Reference points method. Trade-off and marginal rate of substitution.

literature:

- K.Miettinen, Nonlinear Multiobjective Optimization, (Kluwer, 1999).

INFPHD407 Software Testing

short description:

1.1. Introduction
1.2. Fundamentals of software testing, terminology
1.2.1. The testing challenge
1.2.2. Economics of testing
1.2.3. General testing principles
1.2.4. Fundamental test process
1.2.5. The psychology of testing
1.3. Testing throughout the software life cycle
1.3.1. Software development models
1.3.2. Test levels. Test types
1.3.4. Testing related to changes. Maintenance testing
1.4. Static techniques
1.4.1. Static techniques and the test process
1.4.2. Review process
1.4.3. Static analysis by tools
2.1. Test design techniques
2.1.1. Categories of test design techniques
2.1.2. Specification-based or black-box techniques
2.1.2.1. EP, BVA,
2.1.2.2. Decision tables and cause-and effect graphing
2.1.2.3. Orthogonal arrays, all-pairs tables,
2.1.2.4. State transition testing, FSM
2.1.2.5. Use-case testing
2.1.3. Structure-based or white-box techniques
2.1.3.1. Statement testing. Coverage
2.1.3.2. Decision testing
2.1.3.3. Condition testing, MC/DC
2.1.3.4. Path Testing, LCSAJ testing
2.1.3.5. Loop testing
2.1.4. Combinations of black-box and white-box techniques
2.1.5. Experience-based techniques
2.1.6. Defect-based testing
2.1.7. Choosing test techniques
3.1. Test management
3.1.1. IEEE 829 Software Test Documents
3.1.2. Risk and testing

3.1.3. Test organization. Independence, roles, tasks
3.1.4. Test policy, test strategy and test approach
3.1.5. Test planning and estimation
3.1.6. Test process monitoring and control
3.1.7. Incident management
3.1.8. Configuration management
3.2. Tool support for testing
3.2.1. Types of test tools
3.2.2. Effective use of tools: potential benefits and risks
3.2.3. Introducing a tool into an organization

literature:

- D. Graham, E.V. Veenendaal, I. Evans, R. Black: *Foundations of Software Testing*, Thomson, 2007.
- G. Bath, J. McKay: *The Software Test Engineer's Handbook*, O'Reilly, 2008.
- P. Jorgensen: *Software Testing: a craftsman's approach*, CRC Press, 2002.
- R. Binder, *Testing Object Oriented Systems: Models, Patterns and Tools*, Addison-Wesley, 2000.

INFPHD413 Principles of Real Analysis

Short description:

The definition of the gamma functions and their basic properties. The Lebesgue measure of cubes in R^n, Vitali`s lemma.
The regularity of n-dimensional Borel measures. The conditional expectation operator, martingales. Integral inequality of Minkowski. Signed measures, the Hahn and Jordan decompositions. Singular measures, Lebesgue decomposition. Differentiability of Borel measures, the cases of singular and absolute continuous measures. Differentiability of monotonic functions and integral functions. Lebesgue point, theorem of Lebesgue. Absolute continuity. Functions of bounded variation. Jordan`s theorems. The characterization of absolute continuous function. Example for strictly monotonic function with zero derivative almost everywhere. Decomposition of monotonic functions. Derivation of function series, Fubini`s theorem. The concept of density of sets, Lebesgue`s theorem. Integration by parts and substitution. The concept of the Hardy-Littlewood maximal function and its strong (L^p,L^p) (1<p) and (L^1,L^p) (0<p<1) and weak (L^1,L^1) type properties. The space (Llog^+L,L^1), theorem of Stein. The role of the maximal operator of sequence of operators in almost everywhere convergence. Interpolation of operators, Marcinkiewicz`s theorem. The Calderon-Zygmund decomposition. The duals of L^p ($1 \leq p < +\infty$) spaces.

References:

- Simon Péter – Weisz Ferenc, Válogatott fejezetek az analízisből, http://www.inf.elte.hu/karunkrol/digitkonyv/
- Jegyzetek2007/analizisfejezetek.pdf (in Hungarian)
- H. Bauer, Measure and integration theory, (translated from the German by Robert B. Burckel), de Gruyter Studies in Mathematics, 26, Walter de Gruyter, Berlin, 2001.
- J. Elstrodt, Mass- und Integrationstheorie, Springer-Lehrbuch, 2007.
- E. Hewitt-K. Stromberg, Real and abstract analysis, Springer Verlag, Berlin-Heidelberg-New York, 1975.
- Járai Antal, Mérték és integrál, felsőoktatási tankönyv, Nemzeti Tankönyvkiadó, Budapest, 2002. (in Hungarian)
- Laczkovich Miklós, Valós függvénytan, egyetemi jegyzet, ELTE, Budapest, 1995. (in Hungarian)
- E.M. Stein - R. Shakarchi, Real Analysis: Measure Theory, Integration and Hilbert spaces, Princeton Lectures in Analysis, Princeton University Press, 2005.
- Szőkefalvi-Nagy Béla, Valós függvények és függvénysorok, Tankönyvkiadó, Budapest, 1965. (in Hungarian)
- C. Zaanen, Continuity, Integration and Fourier Theory, Springer-Verlag, Berlin-Heidelberg-New York-London-Paris-Tokyo, 1989.

INFPHD417 Research Areas of Interactive Media

type of examination: Doctoral colloquium

Short description:

Exploring the current research questions of Interactive Media, its ubiquitous presence, emerging technologies, R&D trends and its effects on society.

Themes:
Interactive Media
Data Visualization
Interaction Design
User Interfaces
Multimedia Design
Digital Narratives
Learning Media
Museum Technologies
Games Design
Bewildering Codes
Virtual Worlds
Mobile Technologies

Literature:
Entertainment Computing:
http://www.elsevier.com/wps/find/journaldescription.cws_home/717010/description#description
Ubiquitous Learning:
http://ijq.cgpublisher.com/
Virtual Worlds research:
http://matchsz.inf.elte.hu/TT/docs/VWR.htm
Interactive Mobile Technologies:
http://www.online-journals.org/index.php/i-jim
Emerging Technologies in Web Intelligence:
http://academypublisher.com/jetwi/
Emerging Technologies in Learning:
http://www.brandon-hall.com/workplacelearningtoday/?p=9784
Immersive Education initiative:
http://immersiveeducation.org/
International Journal of Arts and Technology
http://www.inderscience.com/sample.php?id=264
International Journal of Interactive Mobile Technologies
http://www.online-journals.org/index.php/i-jim
IEEE Transactions on Learning Technologies
http://www.computer.org/portal/web/tlt

Further updates:
http://intmedia.elte.hu/

INFPHD421 Mobile Ad Hoc Networks
type of examination: Oral exam

short description:
Ad hoc networking is one of the most innovative and challenging areas of networking, one which promises to become increasingly present in our life. A wireless ad hoc network is a decentralized type of wireless network consisting of devices that are autonomously self-organizing in networks. An ad hoc network does not rely on a pre existing infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks. Instead, each node participates in routing by forwarding data for other nodes. The nodes determine the next hop dynamically based on their connectivity.

For a few years now, these networks have been in focus of the networking community. This lecture gives an introduction into the challenges, models and results in this area, like physical issues, medium access (MAC), routing protocols, topology control, location, directed communication, random placement, energy saving, theoretical limits, and the impact of mobility.

literature:

- Y. Wang: Topology Control for Wireless Sensor Networks. *Book Chapter of Wireless Sensor Networks and Applications*, Series: Signals and Communication Technology, edited by Li, Yingshu; Thai, My T.; Wu, Weili, Springer-Verlag, ISBN: 978-0-387-49591-0, 2008.
- H. Karl and A. Willig: Protocols and Architectures for Wireless Sensor Networks. Wiley, ISBN: 978-0-470-09510-2, 2005.

- Friedhelm Meyer auf der Heide, Christian Schindelhauer, Klaus Volbert, Matthias Grünewald: *Congestion, Dilation, and Energy in Radio Networks*, In: *Theory of Computing Systems*, Vol. 37(3), 343-370, 2004.

INFPHD423 Parallel computing in discrete mathematical modelling
type of examination: Oral exam

short description:
The course covers the most important methods in discrete mathematical modelling, with an emphasis on parallel and distributed methods in computationally intensive tasks.
The main topics of the course:

- a short introduction to models and tools of parallel computation (3 weeks),
- overview of discrete methods in mathematical modelling with examples (3 weeks),
- detailed case studies about the use of graphs and combinatorial algorithms in bioinformatics, group theory in solving puzzles (e.g. Rubik's cube), dynamical systems in economics, number theory in cryptology, percolation theory in epidemies (7 weeks).

literature:
George Em Karniadakis, Robert M. Kirby II: *Parallel Scientific Computing in C++ and MPI: A Seamless Approach to Parallel Algorithms and their Implementation*, Cambridge University Press, 2003, 616 pp.
Raimondas Ciegis, David Henty, Bo Kågström, Julius Zilinskas: *Parallel Scientific Computing and Optimization*, Springer, 2009, 276 pp.
Ridgway Scott, Terry Clark, Babak Bagheri: *Scientific Parallel Computing*, Princeton University Press, 2005, 416 pp.
Maurice Herlihy and Nir Shavit: *The Art of Multiprocessor Programming*, Elsevier/Morgan Kaufmann, 2008, 508 pp.
Frank R. Giordano, Maurice D. Weir, William P. Fox: *A First Course in Mathematical Modeling*, Brooks Cole, 2008, 620 pp.
Frederick Marotto: *Introduction to Mathematical Modeling Using Discrete Dynamical Systems*, Brooks Cole, 2005, 400 pp.
D.R.Shier, K.T.Wallenius (szerk.): *Applied Mathematical Modeling: A Multidisciplinary Approach*, CRC, 1999, 472 pp.

INFPHD427 Peer-to-Peer Networks
Type of examination: Oral exam

short description:
The course deals with applications, trends, and challenges of peer-to-peer (P2P) computing. We are addressing current issues as well as emerging concepts and applications, including P2P architectures, search and queries, incentive mechanism, multimedia streaming, theory and analysis.

Topics:
Modeling networks
Unstructured and structured overlay networks
Architecture of Napster, Gnutella, Kazaa
Distributed hash tables (DHT)
CAN architecture, searching, updates
CHORD network, architecture, searching, updates
Pastry
Degree optimal overlay networks, distance halving
BitTorrent
Network coding
P2P streaming
Anonymity, Freenet, Tor

Literature:

- Shen, X.(.; Yu, H.; Buford, J.; Akon, M. (Eds.): Handbook of Peer-to-Peer Networking. Springer, ISBN: 978-0-387-09751-0, 2010.

INFPHD433 Fourier-analysis I.
precondition: Transformations in mathematics

short description:
Investigations of Walsh Fourier and Vilenkin Fourier series. Norm and almost everywhere convergence, different summability methods, approximation. Martingal theory, Hardy- and BMO spaces, atomic decompositions. Interpolation theory. Multi-dimensional theory.

literature:

- Schipp, F.; Wade, W. R.; Simon, P. & Pál, J.:Walsh Series: An Introduction to Dyadic Harmonic Analysis.
  Adam Hilger, Bristol, New York, 1990
- Weisz, F.: Martingale Hardy Spaces and their Applications in Fourier Analysis.
  Springer, Berlin, 1994
- Garsia, A. M.: Martingale Inequalities. Seminar Notes on Recent Progress.
  Benjamin, New York, 1973

INFPHD434 Fourier-analysis II.
precondition: Transformations in mathematics

short description:
Investigations of trigonometric Fourier series and Fourier transforms. Norm and almost everywhere convergence, different summability methods, approximation. Hardy- and BMO spaces, atomic decompositions. Interpolation theory. Multi-dimensional theory.

literature:

- Grafakos, L.: Classical and Modern Fourier Analysis, *Pearson Education, New Jersey,* 2004
- Butzer, P. L. & Nessel, R. J.: Fourier Analysis and Approximation, *Birkhäuser Verlag,* 1971
- Weisz, F.: Summability of Multi-dimensional Fourier Series and Hardy Spaces, *Kluwer Academic Publishers, Dordrecht, Boston, London,* 2002

INFPHD435 Current Trends in Logic Programming
precondition: Art of Logic Programming / Logikai programok építése
covered by Sterling, Shapiro, *The Art of Prolog* (see below **in** literature)
type of examination: performance test

short description:
Basics of logic programming (tutorial: paradigm, language, programming methodology).
Constraint logic programming: goals and constraints, constraint store, full and partial consistency;
transition, derivation, proof; different kinds of constraints, domains, domain-specific constraints,
unification, variable elimination, constraint propagation, local consistency, labelling, program reformulations,
constraint handling rules, top-down and bottom-up evaluation; concurrency, guards; applications.

Parallel logic programming: explicit parallelism (committed choice languages);
implicit parallelism (or-parallelism, and-parallelism), the Andorra programming model and language.
Definite Clause Grammars (DCGs): parsing, error handling; generative DCGs, compiler writing.
Logic grammars as deterministic, top-down parsers *or* bottom-up parsers.
Purely declarative logic programming: strong, static, polymorphic type system, strong mode and determinism system,
fast code, module system, foreign interfaces, enterprise applications: the Mercury functional logic programming language.

literature:

- Clocksin, Mellish, *Programming in Prolog: using the ISO Standard*, Springer, 2003.
- Deransart, Ed-Dbali, Cervoni, *Prolog: The Standard (Reference Manual)*, Springer-Verlag, 1996.
- Richard O'Keefe, *The Craft of Prolog*, The MIT Press, 1990.
- Sterling, Shapiro, *The Art of Prolog* (Second Edition), The MIT Press, London, England, 1994.
- Marriott, Stuckey, *Programming with Constraints: An Introduction*, The MIT Press, London, England, 1998.
- Frühwirth, Abdennadher, *Essentials of Constraint Programming*, Springer, 2003.
- *Documentation for SICStus Prolog 4*, Swedish Institute of Computer Science, Kista, Sweden, 2012. http://www.sics.se/isl/sicstuswww/site/documentation.html

- Haridi, Janson, *Kernel Andorra Prolog and its Computation Model*, Swedish Institute of Computer Science, Kista, Sweden, 1990. http://www.sics.se/~sverker/public/papers/kapiclp90.pdf
- *The Mercury Project*, University Of Melbourne, Victoria, Australia, 2012. http://mercurylang.org/
- Nilsson, U., *AID: An Alternative Implementation of DCGs*, New Generation Computing, No 4, pp.383-399, Vol 4, 1986.
- Jukka Paakki, *A practical implementation of DCGs*, Lecture Notes in Computer Science, Volume 477/1991, Pages 224-225, Springer, 1991.
- Pereira F., Warren D., *Definite clause grammars for language analysis*, Artificial Intelligence, Elsevier, 1980.
- David H. D. Warren, *Logic programming and compiler writing*, Software: Practice and Experience, Volume 10 Issue 2, Pages 97 - 125, Published Online: 27 Oct 2006. (Copyright: 2010 John Wiley & Sons, Ltd.)
- Ásványi Tibor, *DCGs for Parsing and Error Handling*, http://aszt.inf.elte.hu/~asvanyi/pp/dcgs1p3.pdf, 2010.

INFPHD436 Scientific databases

type of examination: oral exam

short description:
The purpose of the class is to introduce students to data warehouse problems of various fields of natural sciences, and to demonstrate their solution using relations database management system. During the semester, master's and doctoral students learn about the hardware and software aspects of designing data warehouses and get a practical introduction into the details of the implementation of these systems, as well as into query optimization. Classes touch upon some special fields of handling scientific data: provisioning large amounts data, handling multi-dimensional data, problems arising from using spherical coordinates and problems of graph databases. Classes primarily focus on row-based relational databases but column and array-based, as well as noSQL solutions are also explained.

Exam items:

- Basics of scientific databases. The fourth paradigm. Scientific data processing in an exponential age. Amdahl's laws, Jim Gray's laws.
- High performance x64 server architectures. Multi-processor system. Caches, caching algorithms, snoop filter.
- Storage systems. Introduction to hard disks. Hardware I/O protocols. RAID systems, RAID configurations. RAID maintenance tasks, typical RAID problems. Software and hardware RAID implementations.
- Properties of RAID 5. Parity bits, writing RAID 5, increase of latency. The write hole.
- Layers of the I/O system. Partition, volume, file system, file API. Redundant volumes. Buffered and unbuffered I/O.
- Synchronous and asynchronous function, outstanding jobs. Measuring I/O performance. Networks.
- Relational database management system. The relational data model. Table, primary key, foreign key. Data storage in row-based relational systems. Page, heap table, clustered index, secondary index. File groups, partitioned tables.
- Properties of indexes. B-trees, differences between clustered indexes and secondary indexes. Index fill factor, index statistics. Optimizing indexes.
- Query execution in SQL databases. Execution steps. Fundamental physical operators.
- JOIN operations. Types of JOIN operations, the different physical JOIN operators.
- Aggregate functions. Implementation of aggregate functions. Physical realization of aggregation. GROUP BY operators.
- Query optimization. Introduction to the problem. Aspects of optimization, the available information, selecting the right index.
- Transactions. Fundamental properties of transactions. Isolation levels. Phantom reads and avoiding them. Locking, dead-lock and avoiding it. Possible outcomes of transactions. Transaction log.
- Backups. Transaction log, recovery models. Replication methods.
- Data provisioning. Problems with scientific data. Typical steps of multi-step data provisioning, advantages of the method. Comparison of BULK INSERT and simple INSERT. Verifying data consistency.

- Meta-data of scientific databases. Ontologies, content identifiers. Provenance, data quality. Connecting scientific data warehouses.
- Indexing of spatial data. Fundamental spatial data structures. Space-filling curves. Preconditioning data for indexing.
- Primary applications of spatial indices.
- Methods of indexing the surface of the sphere.
- Mapping data models to the relational model: trees, graphs. Storing non-structured data.
- Column oriented databases. Storage model. JOIN indexes. Cursors. Continuous address data storage, vectorized operation, importance of JIT compilation.
- Array databases. The storage model. Fundamental problems of array processing. Kernel functions. Continuous address data storage, vectorized operations, importance of JIT compilation.
- Distributed databases. Introduction to primary possibilities and problems. Partitioning opportunities. The questions of replication and consistency. Implementing fundamental physical operations. Main ideas of performing distributed JOINs.
- Introduction to the principles of Hadoop-MapReduce. Programming in the MapReduce model.
- noSQL databases. Simplifications with respect to relational databases. The CAP-theorem. Simplifications of the transactional model. Relaxation of the consistency model, resolving conflicts.

INFPHD437 Variational methods in practice
type of examination: oral exam

short description:
Introduction: classical differential geometry, vector and tensor calculus, variational calculus
Variational methods in physics: applications in classical and relativistic mechanics
Variational methods in Machine Vision:
- Motion analysis: optical flow
- Image reconstruction: TV noise removal, inpainting
- Active contours and surfaces: parametric and geometric methods
- Applications of active contours and surfaces: image segmentation and 3D reconstruction
The Level Set Method

literature:
- Gelfand, I.M. and Fomin, S.V. 1963. Calculus of Variations. Englewood Cliffs, NJ: Prentice-Hall.
- R.Hartley, A.Zisserman, "Multiple View Geometry in Computer Vision", Cambridge University Press
- J.A. Sethian. Level Set Methods and Fast Marching Methods. Cambridge University Press, 2002
- L. Rudin, S. Osher, and E. Fatemi, Nonlinear total variation based noise removal algorithms, Phys. D, 60 (1992), pp. 259–268.

INFPHD438 Requirements Engineering

Short description:
The impact of requirements engineering on successful and customer-oriented systems development can no longer be ignored. The role of a requirements engineer is essentially self-contained and comprises a series of demanding activities.

- Foundations (Communications Theory, Requirement Types and Categorizations)
- System and Context Boundaries
- Eliciting Requirements (Sources, Kano-model, Elicitation Techniques)
- Documenting Requirements (Types, Structures, Glossary, Quality Criteria, Natural Language Documentation, Templates)
- Model-Based Requirements Documentation (Goal Models, Use Cases, Data Perspective, Functional Perspective, Behavioural Perspective)
- Requirements Validation and Negotiation
- Requirements Management (Prioritizing, Traceability, Versioning, Managing Changes)
- Tool Support

Literature:

- Claus Pohl, Chris Rupp: Requirements Engineering Fundamentals, Rocky Nook Inc. (April 2011) 184 Pages, ISBN-13: 978-1933952819
- Karl E. Wiegers: More About Software Requirements: Thorny Issues and Practical Advice, Microsoft Press (2005) 224 Pages, ISBN-13:978-0735622678
- Ian F. Alexander, Richard Stevens: Writing Better Requirements, Addison-Wesley (2002) 176 Pages, ISBN-13: 9 780321 131638

INFPHD439 Enterprise Architecture and Business Process Modelling
type of examination: Colloquium

short description:

1. Enterprise Architecture theories:
    a. Zachman, TOGAF, etc.
2. Business Process Management and Modelling
    a. Concept of Business Process;
    b. Business Process Modelling methods
        i. Event-driven Process Chain (EPC);
        ii. Soft System Methodology;
        iii. BPR (Business Process Re-engineering);
        iv. BPM /BPMN (Business Process Modelling / Notation);
        v. Formal methods: *Process algebra, pi-algebra, Petri nets*
    c. Workflow modelling and management;
    d. Semantics of Business Processes and its modelling methods;
3. From Software Architectures to Enterprise Architecture.
    a. Web technologies, Web Services, Service-oriented Architecture;
    b. Formal methods: *story algebra, business artefacts, document-centric modelling.*
4. Cloud Computing:
    a. Relationship between Web Information Systems, SOA and Cloud Computing;
    b. Business Process Modelling methods in a Cloud Computing environment.
        i. SaaS
        ii. SaaP
        iii. SaaI

literature:

- Hans-E Eriksson, Magnus Penker: Busines Modeling with UML, OMG Press, 2000.
- BPM EA http://www.bptrends.com/reports landing.cfm.
- Object Management Group/Business Process Management Initiative – Business Center Exellence. www.bpmn.org.
- Nathalian Palmer. A Survey of Business Process Initiatives. Technical Report 1, 2007. http://www.bptrends.com/reports landing.cfm.
- CIGREF : ISD project 2010-2012 - dynamique des usages des systèmes d'information. Kutatás az információs rendszerek hatásai és fejlődési irányai 2020-ig–http://www.fondation-cigref.org/programme-isd/
- Molnár Bálint (2002): Bevezetés a rendszerelemzésbe, A rendszerszervezés alapjai, Műszaki Könyvkiadó, 2002. (Kiadói azonosító: MK-00275), http://www.muszakikiado.hu/details.php?details=MK-00275 , http://www.mtaita.hu/Bevezetes.pdf
- Molnár Bálint, 'Bevezetés a rendszerelemzésbe', in: Gábor András (szerk.) „Információmenedzsment", Aula Kiadó, 1997, pp 107-239. http://www.mtaita.hu/hu/Publikaciok/Informaciomenedzsment.pdf
- Marco Bernardo Paola Inverardi (Eds.) Formal Methods for Software Architectures Third International School on Formal Methods for the Design of Computer, Communication and Software Systems: Software Architectures, SFM 2003 Bertinoro, Italy, September 22-27, 2003
- Michele Chinosi, Alberto Trombetta, BPMN: An introduction to the standard, Computer Standards & Interfaces, Volume 34, Issue 1, January 2012, pp.124-134,
- Peter Y.H. Wong, Jeremy Gibbons, Formalisations and applications of BPMN, Science of Computer Programming, Volume 76, Issue 8, 1 August 2011, Pages 633-650, ISSN 0167-6423, http://dx.doi.org/10.1016/j.scico.2009.09.010. (http://www.sciencedirect.com/science/article/pii/S0167642309001282)
- Daniel Minoli, Enterprise Architecture A to Z Frameworks, Business Process Modeling, SOA, and Infrastructure Technology, Auerbach Publications, Taylor & Francis Group, ISBN 978-0-8493-8517-9, 2008

- Marc Lankhorst et al., Enterprise Architecture at Work, 2005, Springer-Verlag Berlin Heidelberg, ISBN-10 3-540-24371-2
- Portougal 2006, Victor Portougal and David Sundaram , Business processes : operational solutions for SAP implementation, 2006, Idea Group Inc., ISBN 1-59140-615-3
- Mathias Weske, Business Process Management, Concepts, Languages, Architectures, © Springer-Verlag Berlin Heidelberg 2007, ISBN 978-3-540-73521-2 ,
- Simha R. Magal (Grand Valley State University), Jeffrey Word (SAP), Essentials of Business Processes and Information Systems, ISBN 978-0-470-23059-6, Wiley , 2010
- Thomas A. Curran, Gerhard Keller, Andrew Ladd, SAP R/3 Business Blueprint: Understanding the Business Process Reference Model, 1998, Prentice Hall, ISBN 0*13-521147-6

INFPHD441 Semantic Web applications
precondition: Basic knowledge of web protocols and web technologies
type of examination: practical

short description:

Semantic Web aims for the provision of machine processable data. Nowadays large quantities of data is accessible in t he format of Linked Data, which can be used for reasoning, visualization and data mining. The course aims to give an overview of methods and tools for creating and processing Linked Open Data and RDF. We will also see how to work with Description Logic ontologies and how to use OWL. Application areas introduced will include semantic search, inferencing, semantic matching, semantic annotation, visualisation, etc.

literature:
- Berners-Lee, Tim; James Hendler and Ora Lassila. "The Semantic Web". *Scientific American Magazine*, May 17, 2001.
- Nigel Shadbolt, Wendy Hall, Tim Berners-Lee. "The Semantic Web Revisited". *IEEE Intelligent Systems*, May/June 2006.
- RDF Primer, W3C Recommendation, February 10, 2004, Frank Manola and Eric Miller, eds.
- SPARQL 1.1 Overview, W3C Recommendation, March 21, 2013
- Markus Krötzsch, František Simančík, Ian Horrocks. A Description Logic Primer. In CoRR abs/1201.4089. arxiv.org 2012.
- Franz Baader, Diego Calvanese, Deborah L. McGuinness, Daniele Nardi, and Peter F. Patel-Schneider (Eds.). 2003. The Description Logic Handbook: Theory, Implementation, and Applications. Cambridge University Press, New York, NY, USA.
- Paolucci, T. Kawamura, T. R. Payne, and K. P. Sycara. Semantic matching of web services capabilities. In International Semantic Web Conference, pages 333–347, 2002.
- László Kovács, András Micsik, Péter Pallinger: Handling User Preferences and Added Value in Discovery of Semantic Web Services. IEEE International Conference on Web Services, ICWS 2007, pages 225-232
- Jorge Ejarque, András Micsik, Raúl Sirvent, Peter Pallinger, László Kovács, Rosa M. Badia: Job Scheduling with License Reservation: A Semantic Approach. PDP 2011: 47-54.

INFPHD444 SAT Solving Algorithms

short description:
The SAT problem is the satisfiability problem of logical formulae in conjunctive normal form. This problem plays a central role in computer science, for example it is the dual of theorem proving and it is NP-complete. In the framework of this course students are going to learn the DPLL algorithm, lazy data structures designed for DPLL and conflict-driven backtrack technologies. We will study the source code of open-source state-of-the-art SAT solvers like miniSAT. We will learn the most well-known heuristics for DPLL, which help the algorithm to find the right variable for splitting. On the theoretical side we will learn unit- resolution, the notion of pure, blocked, and nondecisive literals and the related theories. We will study more well-known SAT solver algorithms like DPL, and SLUR. We will discuss how to make parallel SAT solvers. Finally, we will learn non-complete SAT solver algorithms like Random Walk.

literature:
- Biere, A., Heule, M., Van Maaren, H., Walsh, T.: Handbook of Satisfiability, ISBN 978-1-58603-929-5, IOS Press, February 2009.

- Victor W. Marek: Introduction to Mathematics of Satisfiability, ISBN 978-1-43980-167-3, Chapman & Hall, CRC Studies in Informatics Series, 2009.

INFPHD447 Formal and semi-formal approaches for information security and information architecture

Short description:

1. Formal methods for Information Security
   1.1. Formal model for Information Security
   1.2. Formal modelling of Requirements for Information Security
   1.3. A Trace-Based Model.
   1.4. Verification procedures.
2. Concepts and modelling diagrams,
   2.1. System model
      2.1.1. Tracking, audit trail
      2.1.2. Event-based systems
      2.1.3. State-event systems
   2.2. Specification of Systems' properties
   2.3. Model driven information security
   2.4. Pattern-based methods
3. INFORMATION SECURITY ARCHITECTURE
   3.1. PKI
   3.2. Identity management
   3.3. Time-stamping
   3.4. Requirements for Security Architecture
   3.5. SOA, WEB Security Issues
      3.5.1. WS-Security
      3.5.2. WS-Trust
      3.5.3. XACML
   3.6. Standards for Secure Information Architecture
   3.7. Single Sign On and Federative Identity Management
   3.8. SAML
   3.9. Authorization and Access Rights
   3.10. Role-based Access Rights
4. CLOUD COMPUTING and Security Issues
   4.1. Services provided by the Cloud
   4.2. ERP and Cloud

Literature:

- Hafner, M., & Breu, R. (2009). Security engineering for service-oriented architectures (pp. I-XVI). Berlin, Heidelberg: Springer.
- Site, E., Cuts, R., & In, S. (2008). Security Engineering: A Guide to Building Dependable Distributed Systems. 2ed Editio, 239-274.
- Gertz, M., & Jajodia, S. (2007). Handbook of database security: applications and trends. Springer.
- Macartney, L. A. (2005). Information Security Harmonisation: Classification of Global Guidance. Information Systems Audit and Control Association.
- Killmeyer, J. (2002). Information security architecture: an integrated approach to security in the organization. CRC Press.
- D. Garlan, M. Shaw, An Introduction to Software Architecture, Advances in Software Engineering and Knowledge Engineering, Volume I, World Scientific, 1993.
- Was kostet die Cloud? www.login2work.de (letöltve: 2012. 03. 28.)
- Repschläger, J.-, Zarnekow, R. (Repschläger et al, 2011): IT-Outsourcing und Cloud-Sourcing Gemeinsamkeiten und Unterschiede. ERP Management, Nr. 1/2011, S. 48-51.
- Fröschle, H-P. (Fröschle, 2011): Cloud Computing - Herausforderungen für IT-Management und –Betrieb. ERP Management, Nr. 1/2011, S. 45-46
- von der Dovenmühle. T.-, Gómez, J. M. (Dovenmühle et al, 2011): Datenschutz beim Einsatz von Cloud Computing, ERP Management, Nr. 3/2011, S. 58-60
- D-Grid-Projekts FinGrid (2009): Grid Computing in der Finanzindustrie. Publication 01/2009, efinancelab Frankfurt/M, Books on Demand GmbH, Nordenstadt.
- Racskó P. (2012): A számítástechnikai felhő az Európai Unió egén. Vezetéstudomány, Nr. 1/2012, 2-16. oldal, ISSN: 0133-0179. Budapest, 2012
- Weinman, J. (2012). Cloudonomics: The Business Value of Cloud Computing. Wiley. com.

- The Open Group: Building return on investment from cloud computing. A white paper, cloud business artifacts project. Cloud Computing Work Group (2010).
- Holtz, P. Cloud biztonság, http://www.bitport.hu/biztonsag/cloud-biztonsag-szakertoi-cikk-holtzl-peter (letöltve: 2012.08.07.)
- Bundesamt für Sicherheit in der Informationstechnik(BSI): Eckpunktepapier. Sicherheitsempfehlungen für Cloud-Computing-Anbieter.

INFPHD450 Stochastic Models and Adaptive Algorithms

Short Description:
There are many fields of computer science (from image- and voice recognition, robotics and cyber security to medical-, economical- and industrial applications) in which stochastic approaches should be applied due to significant uncertainties, typically coming from measurement errors, hidden processes, imprecise models and changing environments. This course aims at giving an introduction to the theory of some typical stochastic models and adaptive algorithms widely applied in fields including machine learning, data mining, control theory, signal processing and time-series analysis. The course mainly builds on (undergraduate level) results from linear algebra as well as (multivariate) statistics and analysis. Basic knowledge on supervised- and reinforcement learning is recommended, but not required.

Topics:

(1) *static models:* (pseudo) linear regression, (generalized) least squares, Gauss-Markov theorem;
(2) *static models:* kernel machines (classification, regression), VC dimension, regularization, representer theorem;
(3) *adaptive algorithms:* recursive least squares, (recursive) stochastic gradient, exponential forgetting;
(4) *dynamic models:* autoregressive, moving average, ARMAX, Box-Jenkins, Hammerstein-Wiener, NLARX;
(5) *dynamic models:* maximum likelihood-, prediction error-, correlation-, and instrumental variable estimation, their consistency, asymptotic distributions, and their corresponding confidence regions;
(6) *dynamic models:* Markov decision processes, their main variants, control policies, Bellman optimality equations, value function-, policy search- and linear programming based solution methods;

adaptive algorithms: stochastic approximation: Robbins-Monro, Kiefer-Wolfowitz, SPSA, Q- and TD-learning.

Literature:

- Jerome Friedman, Trevor Hastie, Robert Tibshirani. *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*. 2nd Edition. Springer. 2009.
- Lennart Ljung. *System Identification: Theory for the User*. 2nd Edition. 1999.
- Dimitri P. Bertsekas and John Tsitsiklis. *Neuro-Dynamic Programming*. Athena Scientific. 1996.

Recommended Literature:

- Albert Benveniste, Michel Métivier, Pierre Priouret. *Adaptive Algorithms and Stochastic Approximations*. Springer. 1990.
- Bernhard Schölkopf, Alexaner J. Smola. *Learning with Kernels: Support Vector Machines, Regularization, Optimization and Beyond*. The MIT Press. 2002.
- Harold J. Kushner, G. George Yin. *Stochastic Approximation and Recursive Algorithms and Applications*. 2nd Edition. Springer. 2008.
- Simon O. Haykin. *Neural Networks and Learning Machines*. 3rd Edition. Prentice Hall, 2008.

Vladimir N. Vapnik. *Statistical Learning Theory*. Wiley-Interscience. 1998.

INFPHD451 Numerical solution of problems in Multibody dynamics
Short description:
The subject aims to describe how multibody systems can be mathematically modelled and solved with analytical and numerical methods. Basic mechanical systems are to be analyzed such as projectile motion, body slipping on an inclined plane, one and two-degreeof-freedom pendulum. The second half of the semester deals with complex engineering mechanisms, built and analyzed in ADAMS, like cranes, four-membered mechanisms, crankshaft-valve mechanisms.

INFPHD452 Mathematical methods in cryptography
Short description:

The course covers several mathematical methods related to well-known and unorthodox cryptographic methods and applications. The main goal is to present the underlying theoretical methods behind the particular cryptographic protocols and show non-trivial connections between various aspects.
The main topics of the course:

- elliptic curve cryptography
- lattice based cryptography
- cryptosystems based on number theoretic arguments
- secret sharing

Literature:

- Darrel Hankerson, Alfred Menezes, and Scott Vanstone: *Guide to Elliptic Curve Cryptography*, Springer, 2004
- Jeffrey Hoffstein, Jill Pipher, Joseph H. Silverman: *An Introduction to Mathematical Cryptography*, Springer 2014
- Jonathan Katz, Yehuda Lindell: Introduction to *Modern Cryptography*, Chapman & Hall/CRC 2007

IV. Rules for evaluation and assessment:

In the Doctoral School, credit points can be given in the scholastic training module for attending contact hours, for exams, for the preparation of the accomplishment of tasks and for the absolving of assessments.

In the case of one-semester courses, which are taught in one or two hours a week, the assessment of the adaptation and acquirement of the store of learning (performance) is carried out on a five-level scale: excellent (5), good (4), satisfactory (3), pass (2), fail (1).

Some courses can specially classified as preparations for the complex exam (see the list below). At least one of this type of courses has to be fulfilled by the fourth semester, the course has to be the part of the complex exam's course-frame.

In the scientific module, credits may be given for obtaining abilities and skills necessary for research activities, for progress in the research work, for the publication of research results. Assessment of performance of research activity is carried out on a three-scale system: [excellent, satisfactory, unsatisfactory].

The supervisor certifies the research results at the end of each semester by filling in the "certificate of credits" form, and determines the credit value of professional presentations, presentations and posters in conferences abroad and in the home country, and accepted/or published papers in Hungarian or in a foreign language. Research without concrete results is evaluated by the supervisor in proportion to the invested amount of work.

PhD students may undertake teaching tasks. Teaching credits may be given for regular teaching activities at the Faculty of Informatics, and on extra request for teaching activities in external institutions. The amount of credits given for the activities in the Teaching module are certified by the head of department responsible for the teaching of the course.

First year PhD students have to prepare a detailed research plan at the end of the first semester. The research plan is evaluated by the supervisor on a two-level scale [satisfactory, unsatisfactory].

The programme council of the Doctoral School of Computer Science overviews the activities and results of the PhD students at the end of the third and the eighth semesters of their studies.

During the report, the PhD students have to prepare a written summary in which they detail the accomplishment of their study duties, their scientific results and publications. The PhD students give an open presentation in front of the leadership of the Doctoral School, and their supervisor about their report and the further schedule of their work.

During the maximum 15 minute long oral presentations, which are based on the previously issued written reports, the PhD students present their PhD topics, the achieved scientific results and their publications.

The PhD-student has to make a research document (report) at the end of the last semester before the complex exam. This document will be examined by the supervisor and the head of the doctoral program.

The list of subjects of the complex exam has to be compiled according to the doctoral programs.

The theoretical courses of the complex exam (also a list of courses that prepare for the complex exam during the training and research phase):

- Databases and knowledge bases
- Information systems
- Design and analysis of algorithms
- Complexity
- Fourier analysis and its applications
- IT security
- Computer algebra
- Artificial Intelligence
- Numerical computations
- The teaching methodology of Information Technology
- Parallel and Distributed Systems
- Programs correctness and semantics
- Programming methodology
- Programming Languages
- Theoretical Foundations of Computer Science
- Computer Graphics
- Computer Systems

Recommended courses:

- Data Mining
- Data Structures and Algorithms
- Approximation Theory
- Bioinformatics
- Numerical solution of differential equations
- Numerical solution of the equation system
- Models of computation and their applications
- Fractal geometry, chaos
- Mathematical modelling of Curves and Surfaces
- Information Theory and Coding
- Information systems applications
- Image Processing (Computer Vision)
- Modern databases
- Mathematical Logic
- Neural Computing
- Programming Technology
- Temporal Logic
- Geoinformatics
- Mathematics of networks and the www