MASTERS COURSE
Internet Technologies and Information Systems
LargeModule Catalogue

List of Modules

1 1.01 Distributed Algorithms

Lecturer	Prof. Dr. Fekete, Sándor (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1050
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

Many aspects of our complex world are not controlled by a central authority, but work in a decentralized, distributed fashion, where many processors use local information and communication to achieve global objectives. This class deals with algorithms for these kind of scenarios.

Among the most important aspects are the following:

(1) Models, bounds, complexities, computability

(2) Basic network algorithms and structures, communication paradigms

(3) Local and self-stabilizing algorithms

(4) Asynchronous and synchronous networks

(5) Geometric and wireless sensor networks

Outcomes

On completion of this module, the student will know about the necessity and the eligibility of distributed algorithms. He/she is proficient in the most important techniques for distributed algorithm analytics and design.

In addition, students will be able to analyze current state-of-the-art literature, evaluate the finer points of given approaches, and apply principles and methods in a variety of scenarios.

Recommended Literature

Nancy Lynch: Distributed Algorithms
David Peleg: Distributed Computing: A Locality-Sensitive Approach

Dorothea Wagner und Roger Wattenhofer: Algorithms for Sensor and Ad Hoc Networks, Advanced Lectures. Springer Verlag.

In addition, current research articles will be provided.

Recommended Prerequisite Knowledge

Basic knowledge and experience with algorithms, as obtained in undergraduate classes on algorithms and data structures and discrete algorithms

Teaching Methods

blackboard lecture/video-taped

2 1.02 Online Algorithms

Lecturer	Prof. Dr. Fekete, Sándor (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1045
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Summer (biyearly)

Description

In many important real-life situations, the input data for an algorithm is incomplete and only becomes available during runtime. Dealing with these kind of scenarios gives rise to online algorithms.

Participants will learn fundamental modeling, design and analysis of online algorithms.
Topics include:

(1) Competitive Analysis
(2) Self-Organizing Data Structures
(3) Distributed Paging
(4) Online Scheduling
(5) Robot Motion Planning (Exploration, Search)
(6) Online Packing

Outcomes

On completion of this module, the student will know the necessity and the eligibility of distributed algorithms. He/she is proficient in the most important techniques for online algorithm analytics and design.

In addition, students will be able to analyze current state-of-the-art literature, evaluate the finer points, and apply principles and methods in a variety of scenarios.

Recommended Literature

Allan Borodin: Online Computation and Competitive Analysis.
Amos Flat & Gerhard Woeginger: Online Algorithms.

In addition, current research articles will be provided.

Recommended Prerequisite Knowledge

Basic knowledge and experience with algorithms, as obtained in undergraduate classes on algorithms and data structures and discrete algorithms

Teaching Methods

blackboard lecture/video-taped

3 1.03 Modal Logics

Lecturer	Prof. Dr. Dix, Jürgen (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	1040
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25 min)
Semester	periodically, according to student demand and staff specialisms

Description

The module gives a broad introduction to modal logics. These logics are used as description formalisms for describing computations in a system. They allow to express that something will be the case in the future or that certain properties hold along certain paths. It is shown how modal logics can be used to model and to reason about knowledge and public announcements in multi-agent systems.
The advanced part includes the analysis of the expressiveness of modal languages, and characterization and completeness results are proven. In particular, it is shown that the basic modal language cannot distinguish between certain relational structures and that it has the finite model property.

Outcomes

On completion of this module, the student will be able to
- understand the principles of modal logics.
- explain the different calculi for these logics.
- discuss the different modal logic systems, both on the syntactical and the semantical level.
- describe how to use modal logics in describing several aspects of computing systems.
- be aware of the intricate relationship between modal logics and first-order logic.
- understand the method of canonical models used in the completeness proofs.
- understand the relationship between modal logics and predicate logic.

Recommended Literature

- Patrick Blackburn, Maarten de Rijke, und Yde Venema. Modal Logic. Cambridge University Press, 2002.
- Patrick Blackburn, Frank Wolter, und Johan Van Benthem. Handbook of Modal Logic, Elsevier Science & Technology, 2006.
- Hans van Ditmarsch, Wiebe van der Hoek, und Barteld Kooi. Dynamic Epistemic Logic. Springer-Verlag, 2007.
- Michael Huth und Mark Ryan. Logic in Computer Science: Modelling and Reasoning about Systems. Cambridge University Press, 2004.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of first order logic as, for example, acquired through an introductory module on theoretical computer science at undergraduate level.

Teaching Methods

Beamer presentation, whiteboard, homework

4 1.04 Complexity Theory

Lecturer	Prof. Dr. Dix, Jürgen (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	1035
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25 min)
Semester	periodically, according to student demand and staff specialisms

Description

The module gives a broad introduction to complexity theory. Starting from Ehrenfeucht's theorem, we discuss Post's correspondence theorem and consider the boundary between decidable and undecidable problems. This includes the discussion of recursive functions and their correspondence to Turing machines. More advanced results about recursive functions, which reflect interesting properties of programs, are proven. Some important space and time complexity classes are analyzed; in particular, it is shown how the polynomial hierarchy relates to Oracle Turing machines.

Contents:
• (Un-) Decidability, From Ehrenfeucht's theorem to Post's Correspondance theorem, Hilbert's 10th problem, recursive functions, Rice, Makanin
• Space vs Time, Space compression, Speed-up, strict hierachies for space and time, Borodins gap theorem, Blums theorem, Union theorem
• EXPSPACE, Complexity Classes: From L to NEXPSPACE, Oracles, Polynomial Hierarchy, PSPACE
• Arithmetical Hierarchy, arithmetical formula, definable sets, Gödel's theorem about N

Outcomes

On completion of this module, the student will be able to
- understand the different principles of measuring complexity: based on formal automata, their extension to the undecidable, descriptive complexity.
- explain the polynomial hierarchy, the structure of P/NP.
- recognise and understand the theory of primitive recursive functions and its impact on Hilbert's 10th problem.
- understand the theorem of Rice.
- discuss the different relations between time and space complexities.
- describe the difference between Presburger arithmetic and the theory of the natural numbers with multiplication.
- be aware of the arithmetical hierarchy, and Gödel's theorem about the natural numbers.

Recommended Literature

- Christos M. Papadimitriou. Computational Complexity. Addison-Wesley, 1994.
- Michael R. Garey und David S. Johnson. Computers and Intractability. Freeman, 1979.
- Michael Sipser, Introduction to the Theory of Computing. Itps Thomson Learning, 1997.
- John E. Hopcroft, Rajeev Motwani, und Jeffrey D. Ullman. Introduction to Automata Theory, Languages, and Computation. Addison-Wesley Longman, 2006.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of formal languages and theoretical foundations as, for example, acquired through an introductory module on theoretical computer science at undergraduate level.

Teaching Methods

Beamer presentation, whiteboard, homework

5 1.05 Multi-Agent Systems

Lecturer	Prof. Dr. Dix, Jürgen (Clausthal)
Weekly Composition	2L+2E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	1030
Exam Type	Written or oral exam, graded
Exam Duration	Written (120) / oral (25 min)
Semester	periodically, according to student demand and staff specialisms

Description

The module gives a broad overview of theoretical aspects important for multi-agent systems where the focus is on decision making techniques and logical approaches.

The decision making part is comprised of game theoretical approaches, voting mechanisms and auctions. It is shown how these tools can be used to analyze the behavior of agents and as a means to make rational decisions and agreements. The theory of mechanism design is also presented along with its main results and techniques.

The part on logics begins with a brief recall of propositional logic and gives an overview of the main ingredients of modal logic. Then, more advanced logics used for temporal systems and multi-agent systems are presented. In the last section it is shown how first-order logic and temporal logic can be used to program agents.

Contents:
• Introduction. Agents and formal descriptions
• Basic Architectures. Reactive agents, BDI-architectures, agent-oriented programming, layered architectures
• Decision Making I. Non-cooperative game theory
• Decision Making II. Voting, auctions, and market mechanisms
• Nets and Coalitions. Contract nets, coalition formation, Payoff division
• Mechanism Design. Gibbard-Satterthwaite theorem, algorithmic MD, truthful, Bayes-Nash equilibrium
• Modal Logic. S5 logics, Kripke semantics, S5 axioms, normative reasoning
• Action/Time as Modalities. Linear and branching-time logics, dynamic logic, ATL, BDI, verification of systems

Outcomes

On completion of this module, the student should be able to
- explain and compare basic agent based architectures.
- understand decision making techniques based on game theory, voting, and auctions.
- know about task allocation and coalition formation methods.

- understand the principles of propositional logic, modal logics, and extensions of it and how they can be used for multi-agent systems.

Recommended Literature

- Y. Shoham, and K. Leyton-Brown. Multi Agent Systems. MIT Press, 2007.
- G. Weiss. Multi-agent Systems, 1999.
- M. Wooldridge. An introduction to Multi Agent Systems. John Wiley & Sons, 2002.
- M. Wooldridge. Reasoning about Rational Agents. MIT Press, 2000.
- Michael Huth and Mark Ryan. Logic in Computer Science: Modelling and Reasoning about Systems. Cambridge University Press, 2004.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of formal languages and theoretical foundations as, for example, acquired through an introductory module on theoretical computer science at undergraduate level.

Teaching Methods

Beamer presentation, whiteboard, homework

6 1.06 Advanced Logics

Lecturer	Dr. rer. nat. Meier, Arne (Hannover)
Weekly Composition	2L + 1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1025
Exam Type	Oral exam, graded
Exam Duration	25 min
Semester	periodically, according to student demand and staff specialisms

Description

This lecture will cover logical calculi and formalisms used for the description of complexity classes, databases, reactive systems, finite and infinite state systems. Particular emphasis is put on modal logics and their complexity. In this context the technique of Post's lattice is introduced. Further two fundamental results in descriptive complexity are visited.

Outcomes

The students acquire competence in applying advanced logical techniques, analysis of efficient methods, and logical characterizations of complexity classes. They can use important modal logics to describe problems and proving their hardness connected to specific Boolean concepts. Students obtain expertise in proving complex results for problems situated in the area of modal logic. Further the students understand the benefit of the different extensions of modal logics investigated in the lecture and how to classify the corresponding problem in these logics. One main outcome is to understand model checking and its importance for computer science from the computational complexity point of view.

Recommended Literature

N. Immerman, Descriptive Complexity, Springer, 1998.
L. Libkin, Elements of Finite Model Theory, Springer, 2010.
P. Blackburn et al., Modal Logic, Cambridge, 2002.

Recommended Prerequisite Knowledge

Foundations on Computational Complexity, Algorithms, Propositional Logic, NP-completeness

Teaching Methods

whiteboard lecture in combination with slides, video recording

7 1.07 Algorithms and Complexity

Lecturer	Prof. Dr. rer. nat. Vollmer, Heribert (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1020
Exam Type	Oral exam, graded
Exam Duration	25 min
Semester	Winter (biyearly)

Description

We will cover different complexity classes obtained using polynomial-time Turing machines operating under different acceptance criteria. The obtained classes are of current focal interest in the areas of algorithms and complexity, and are the most used for the complexity classifications of algorithmic tasks from areas such as network optimization, knowledge represenation, operations research, etc.

Outcomes

Competence in applications of phenomena of complexity. Ability of detailed analysis and complexity classification of algorithmic problems in terms of (completeness in) polynomial classes (deterministic, parallel, randomized) such as P, NP, PSPACE, PP, etc.
Students are able to distinguish between several important complexity class degrees within the polynomial time hierarchy.

Recommended Literature

Lane Hemaspaandra und Mitsunori Ogihara, The complexity theory companion, Springer.
Christos M. Papadimitriou. Computational Complexity. Addison-Wesley, 1994.
Michael R. Garey und David S. Johnson. Computers and Intractability. Freeman, 1979.
Michael Sipser, Introduction to the Theory of Computing. Itps Thomson Learning, 1997.
John E. Hopcroft, Rajeev Motwani, und Jeffrey D. Ullman. Introduction to Automata Theory, Languages, and Computation. Addison-Wesley Longman, 2006.

Recommended Prerequisite Knowledge

Foundations on computational complexity, algorithms.

Teaching Methods

blackboard lecture, video recording

8 1.08 Efficient Algorithms

Lecturer	Dr. rer. nat. Meier, Arne (Hannover)
Weekly Composition	2L + 1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1015
Exam Type	Oral exam, graded
Exam Duration	25 min
Semester	periodically, according to student demand and staff specialisms

Description

The lecture covers efficient algorithms for fundamental graph-theoretic and number-theoretic problems. The focus lies on the design and analysis of algorithms, including correctness proofs for algorithms and estimates for their running time.

Outcomes

After completion of this module one achieves the ability
- to explain different types (unweighted, positively weighted, negatively weighted graphs) of efficient shortest path algorithms, matching algorithms, time-table algorithms, flow algorithms
- to prove the correctness of these algorithms
- to measure the complexity of these algorithms

Also the student is able to explain and prove results from graph theory w.r.t. coloring problems. Further the student understands the different types of parallel algorithms and the underlying concepts. He explains subtle parallel algorithms with respect to sorting, counting and graph theory problems as connected components and minimal spanning trees.

Further he achieves competence in selected combinatorial problems and efficient techniques for their solution; ability to design and analyze efficient algorithms. Expertise to improve strategies to solve demanding problems.

Recommended Literature

T. Cormen, C. Leiserson, R. Rivest, and C. Stein: Introduction to Algorithms, McGraw-Hill, 2nd edition, 2003.
R. Motwani, P. Raghavan: Randomized Algorithms, Cambridge University Press, 1995.
A. Aho, J. Hopcroft, J. Ullman: The Design and Analysis of Computer Algorithms, Addison-Wesley, 1974.
R. Diestel: Graph Theory, Springer, 3rd edition, 2006.

Recommended Prerequisite Knowledge

Basic Knowledge in Algorithms, Data Structures and Complexity.

Teaching Methods

whiteboard lecture in combination with slides, video recording

9 1.09 Formal Languages

Lecturer	Dr. rer. nat. Meier, Arne (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1010
Exam Type	Written or oral exam, graded
Exam Duration	Written (75 min) / oral (25 min)
Semester	Winter (biyearly)

Description

The classes of regular and context-free languages play an extemely important role in different areas of computer science such as compilers, knowledge representation, web design, etc. In this lecture we will mainly study these classes and their algorithmic properties.

Outcomes

Reach a deep experience for phenomena from the area of formal languages, know how and when use different automata and grammar models for (subclasses of) regular and context-free languages, competence of different transformations, normal forms and further algorithms for these models, applications to syntax analysis, parsing, knowledge representation.

Recommended Literature

John Hopcroft, Rajeev Motwani, Jeffrey Ullman, Introduction to automata theory, languages, and computation, Addison Wesley, 2008.

Recommended Prerequisite Knowledge

Foundations on automata models, Turing machines, Chomsky hierarchy.

Teaching Methods

blackboard lecture, video recordings available at Stud.IP

10 1.10 Information and Coding

Lecturer	apl. Prof. Dr. Damm, Carsten (Göttingen)
Weekly Composition	3L + 1E
ECTS	6
Working Hours (presence/self-study)	56 / 94
Exam ID	1005
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) or Oral (25min), graded
Semester	periodically, according to student demand and staff specialisms

Description

This module gives an introduction into classic topics of communication theory, in particular the theory and construction of error correcting codes. Topics from information theory (like Shannon-theorems on channel capacity etc.) will be included as far as necessary. Emphasis is put on studying error-correcting code constructions. We study: classical code families (e.g., Hamming, Reed-Solomon, Reed-Muller, ..) and their encoding/decoding, compexity of decoding problems, compound constructions like concatenation etc., applications of error correcting codes.
In exercises we will make use of computer algebra systems to construct the codes we study in software.

Outcomes

On completion of this module, students understand aims and methods of error control coding, its role in communication systems, and some of the computational aspects involved. They know the basic designs, theoretical foundations, and some practical applications. They have a good understanding of the combinatorial bounds for existence of codes and can apply them in the concrete and in the asymptotic setting. They can analyse the algorithmic problems related to code construction. The are able to apply standard construction techniques for codes like extension, puncturing, expurgation, concatenation and can analyse the results. Students have a deep understanding of the ubiquitous Reed-Solomon-codes and cyclic codes and the corresponding algebraic techniques as well as their applications (like CD/DVD encoding). They know some of the less structured approaches (like LDPC codes) and their recent success in selected applications.

Recommended Literature

see list at
http://www.citeulike.org/user/damm/tag/ecctexts

Recommended Prerequisite Knowledge

participants should have a basic knowledge in linear algebra, finite fields and elementary probability theory

Teaching Methods

whiteboard lecture (video-taped) with occasional slide presentation (slides will be uploaded), individual homework/lab exercises.
(Homework solutions are to be uploaded by participants for consideration.)

11 1.11 Computer Security and Security Protocols

Lecturer	Prof. Dr. Dix, Jürgen (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	1055
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

The course focusses on the modelling and verification of security protocols; however, basic concepts of cryptography and computer security are considered as well.

The lecture is composed of the following three blocks:

Block I: Basics aspects of computer security, cryptography and its underlying mathematical theory.
(Crypto systems, symmetric and asymmetric encryption, RSA, signatures, key exchange, user authentication, data integrity algorithms)

Block II: Security Protocols: Analysis and Verification Methods.
(Protocols for authentication and key establishment, conference key and password based protocols, verification techniques and tools)

Block III: Various Theoretical Aspects about Security Protocols and their Verification.
(Decidability and undecidability
of automatic verification, logic-based approaches)

Outcomes

On completion of this module, the students have learned how to apply their theoretical foundations from this course to design and analyse real-life security protocols. They are able to apply automatic tools for the verification of security protocols and have a basic understanding of how they work. Moreover, the students are aware of the limits of automatic verification techniques and have a basic understanding of computer security and cryptographic concepts.

Recommended Literature

-Boyd and Mathuria, Protocols for Authentication and Key Establishment, Springer, 2003.
-Buchmann, Einführung in die Kryptography, Springer, 2010.
-Stallings, Cryptography and Network Security, Pearson,2010.
-Stallings, Computer Security, Pearson,2012.

-Cortier, V., Kremer, S., Formal Models and Techniques for Analyzing Security Protocols, IOS Press, 2011.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of theoretical computer science foundations as, for example, acquired through an introductory module on theoretical computer science at undergraduate level.

Teaching Methods

Beamer presentation, whiteboard, homework

12 1.12 Selected Topics in Artificial Intelligence

Lecturer	Prof. Dr. Dix, Jürgen (Clausthal)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	1060
Exam Type	Written Report and Oral Presentation
Exam Duration	Oral presentation (30-45min)
Semester	periodically, according to student demand and staff specialisms

Description

This seminar is dedicated to the discussion of trends and recent advances in the field of artificial intelligence. You are provided exposure to topics beyond the standard curriculum.

In the beginning of the semester, instruction is given in how to review research literature, devise research talks and essays, find relavant background literature, and practise presentation skills.

For the seminar you will read a research paper, prepare an oral presentation emphasising the research goals, methods, and solutions proposed in the paper, and deliver the presentation in class. For your presentation you will receive feedback from the lecturer and your peers. Taking into account the feedback you will then write a essay reviewing the chosen paper and elaborating the subject by gathering more background information. You will also attend the presentations by your peers, and participate actively in class discussions that accompany their presentations.

Outcomes

On successful completion of the module, you will be able to read and analyse research literature, identify research questions and strategies used for their settlement, review research contributions, communicate effectively through technical presentations and written essays, critique presentations, and engage in research-oriented discussions.

Recommended Literature

Varies every semester depending on topic. As the seminar has its focus on current directions in research, the recommended literature will mainly consist of recent articles from topic-specific international conferences or journals.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of artificial intelligence as, for example, acquired through an introductory module on artificial intelligence at undergraduate level.

Teaching Methods

Student presentations, group discussions

13 1.13 Model Checking

Lecturer	Dr. Huhn, Michaela (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	1065
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25 min)
Semester	periodically, according to student demand and staff specialisms

Description

This module will give a broad overview over formally founded, model-based verification methods and techniques used for dependable IT systems, software and hardware. Already in early design phases the precise modelling of the system often reveals inconsistencies and incompleteness which saves the enormous costs of late redesign due to critical findings in traditional testing or after commissioning. The lecture introduces state-transition-systems that form a mathematically precise model suitable to capture the behaviour of industrial-size sequential and distributed programs as well as of hardware components. Then specification formalisms for classes of relevant system properties are presented. The focus of the lecture is on the data structures and algorithms used for exhaustively exploring a state-transition system whether it satisfies a specified property, the so-called model checking techniques.

Outcomes

On successful completion of this module, the students know the logical and graph-theoretic foundations and practically applicable model checking tools for dependable systems. Also, they have deep understanding of basic and enhanced data structures and algorithms.
This enables students to identify and recognize typical application scenarios for formal modelling and verification. They are able to identify the core components of a system and the critical behavioural properties. They are able to formally model the system and specify the requirements using common formal notations. The students are capable of applying model checking techniques and tools as it is highly recommended for dependable systems. Students are aware of the principal limitations of model-based verification as well as of practical restrictions due to complexity issues, because they know about the capabilities and limits of model checking, and the purpose, strength, and weaknesses of the most common algorithms and system representations. Students are also able to propose heuristic techniques and strategies for dealing with common complexity issues in model checking.
In addition, the students learn to deal with scientific source material by working with state-of-the art scientific publications which go far beyond typical capabilities of currently available tools.

Recommended Literature

- C. Baier & J.-P. Katoen: Principles of Model Checking, MIT Press, ISBN 026202649X
- D. Peled: Software Reliability Methods, Springer, ISBN 1441928766

- K. Schneider: Verification of Reactive Systems: Formal Methods and Algorithms, Springer, ISBN 3642055559

Recommended Prerequisite Knowledge

The module presumes a prior understanding of automata theory and logic as, for example, acquired through an introductory module on theoretical computer science at undergraduate level.

Teaching Methods

Slide presentation, lab exercise, group and individual homework

14 1.14 Approximation Algorithms

Lecturer	Prof. Dr. Fekete, Sándor (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1070
Exam Type	Written or oral exam, graded
Exam Duration	120min (if written), 25 min (if oral)
Semester	Summer (biyearly)

Description

Many interesting and natural algorithmic problems (e.g., the Traveling Salesman Problem) are NP-complete--hence, we cannot expect to find a "perfectälgorithm that (i) always and (ii) fast finds (iii) an optimal solution. However, hard problems still need to be solved!

In this class we consider algorithms that do not necessarily find an optimal solution, but that (i) always and (ii) fast find a (iii) provably good solution.

Prerequisites are knowledge of algorithms and data structures, basic graph problems and graph algorithms (e.g., as provided in the lecture "Netzwerkalgorithmen"); basic knowledge from theoretic computer science (NP-completeness) are helpful, but will definitely be supplemented.

Among the topics of this class are:

(1) A basic introduction to NP-completeness and approximation

(2) Approximation for vertex and set cover

(3) Packing problems

(4) Tour problems and variations

(5) Current research problems

In the context of various problems, a wide spectrum of techniques and concepts will be provided.

Outcomes

On completion of this module, the student knows the necessity and the eligibility of distributed algorithms. He/she is proficient in the most important techniques for approximation algorithm analytics and design.

In addition, students will be able to analyze current state-of-the-art literature, evaluate the finer points, and apply principles and methods in a variety of scenarios.

Recommended Literature

Vazirani, Vijay V.: Approximation Algorithms, Springer-Verlag, 2001.

Approximation Algorithms for NP-hard problems edited by Dorit S. Hochbaum, PWS Publishing, 1997

Recommended Prerequisite Knowledge

Basic knowledge and experience with algorithms, as obtained in undergraduate classes on algorithms and data structures and discrete algorithms

Teaching Methods

Blackboard lecture/video-taped

15 1.15 Computational Geometry

Lecturer	Prof. Dr. Fekete, Sándor (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	1075
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25 min)
Semester	periodically, according to student demand and staff specialisms

Description

This module covers computational geometry, i.e., developing algorithmic solutions for geometric problems, which is a very active and current research area that has relevance for a wide range of applications, based on a thorough understanding of the underlying theory.

Topics include:
1. Geometric Problems and Data Structures
2. Triangulation
3. Localization
4. Voronoi Diagrams
5. Convex Hulls
6. Motion planning for robots

Outcomes

After the course, the participants know the basic models of geometric algorithms. They are able to identify algorithmic difficulites of geometric problems and are able to formulate adequate objectives. They can handle different solution techniques and are able to develop algorithmic methods for yet unknown problems. They survey the practical relevance of problems and solutions.

Students will learn about algorithms that are integral to solving geometric problems. They will be able to apply their knowledge to develop algorithmic solutions for new problems and applications.

Recommended Literature

Mark de Berg, Marc van Kreveld, Mark Overmars and Otfried Schwarzkopf: Computational Geometry: Algorithms and Applications, Second. Edition, pages 367, Springer-Verlag, 3rd edition, 2008.

Recommended Prerequisite Knowledge

Basic knowledge and experience with algorithms, as obtained in undergraduate classes on algorithms and data structures and discrete algorithms

Teaching Methods

Blackboard lecture/video-taped

16 1.16 Model Driven Software Engineering

Lecturer	Dr. Huhn, Michaela (Clausthal)
Weekly Composition	2L+1E
ECTS	6
Working Hours (presence/self-study)	56 / 94
Exam ID	1080
Exam Type	Oral exam, graded
Exam Duration	oral (25 min)
Semester	Summer

Description

In model driven development (MDD) of software, models are not only used to visualize, to document, and to specify a software system, but models are considered the core artifacts in a seamless, tool-supported development process. In MDD, numerous parts of a software system are generated automatically from models. Model-driven development promises an increase in productivity and shorter production cycles provided the MDD concepts and techniques for automation fit well to the domain and its prevalent technologies.
In the lecture we introduce various usage scenarios for model driven software engineering, its foundations, concepts and techniques. We consider the design of a problem-specific domain-specific language (DSL) and the implementation of an infrastructure supporting an DSL. In the simplest case, the infrastructure consists of a graphical or textual editor. Later, techniques for parsing, model analysis and model transformation, in particular code generation, are studied. In order to practise on case studies and examples, the Eclipse Modeling Framework with its numerous plugins is introduced.

Outcomes

On completion of this module, the students
* know various usages of model driven software engineering and domain-specific languages (DSL) in system and software design.
* have a clear understanding of the basic concepts, theoretical foundations, and methods that are employed
* are able to apply techniques and tools to design a DSL for a specific purpose and
* are able to implement an infrastructure supporting the DSL like a textual or graphical editor, a parser, various model analysis and model transformations as code generators.
* know how to deal with a wide-spread IDE for model driven development, namely the Eclipse Modeling Framework.
Students are aware of the benefits and drawbacks of MDSE, and know about the challenges arising from the current techniques and tool environments.

Recommended Literature

M. Völter: DSL Engineering - Designing, Implementung and Using Domain-Specific Languages, 2013

Recommended Prerequisite Knowledge

- Modeling languages (e.g. UML) in software development
- Java programming

Teaching Methods

Slide show, Blackboard, Whiteboard

17 2.01 Multimedia Database Retrieval

Lecturer	Prof. Dr. Balke, Wolf-Tilo (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2080
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

Audio and video files are becoming more important in our daily work as well as our leisure lives. In contrast to earlier times, today's storage capacities and transmission bandwidths can easily cope with large amounts of data. But still, effective search and efficient retrieval of this audio-visual data is not supported properly, and still mainly relies on external meta-data in most state-of-the-art systems.
In this module, selected aspects of multimedia database systems are investigated and insights on the used techniques are given. In particular, the module deals with content-based retrieval of multimedia data. The fundamental question is the efficient storage and the later retrieval of multimedia documents. Commonly used retrieval models, as well as an comparison of different auio-visual database techniques are discussed. Typical features of current (commercial) database systems for multimedia information processing are also presented.

Outcomes

On completion of this module, the students have been made aware of the challenges and problems which arise from multi-media retrieval and multi-media storage. This covers technical aspects (algorithms, implementations, etc.) and also psychological aspects (e.g. psycho-acoustics, perceived similarity, lossy compressions, etc.). Furthermore, the students will be able to discuss the strengths and weaknesses of different approaches to multi-media retrieval and will be able to competently propose solution strategies to presented problem scenarios.
Furthermore, due to the topic's actuality and the steady progress of the scientific community, students will have to deal with scientific source material, increasing their awareness for proper scientific workflows.

Recommended Literature

Current literature is provided in form of scientific references.

Castelli & Bergman: Image Databases. Search and Retrieval of Digital Imagery. Wiley, 2002
Baeza-Yates & Ribeiro-Neto. Modern Information Retrieval. Addison-Wesley, 1999.
Parsons. The Directory of Tunes and Musical Themes. Spencer Brown, 1975.
van Rijsbergen. Information Retrieval. Butterworths, second edition, 1979.

Recommended Prerequisite Knowledge

Basic understanding of database technologies. Nevertheless, this module is mostly self-contained and should not pose a problem even if no prior database knowledge is present.

Teaching Methods

slide presentation, home work, discussions

18 2.02 Information Retrieval and Web Search Engines

Lecturer	Prof. Dr. Balke, Wolf-Tilo (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2075
Exam Type	Written or oral exam, graded
Exam Duration	Written (90 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

The module gives an introduction to Web Information Retrieval with particular emphasis on the algorithms and technologies used in the modern search engines.
It covers an introduction to traditional text IR, including Boolean retrieval, vector space model as well as tolerant retrieval. Afterwards, the technical basics of Web IR are discussed, starting with the Web size estimation and duplicate detection followed by the link analysis and crawling. This leads on to the study of the modern search engine evaluation methods and various test collections. Finally, applications of classification and clustering in the IR domain are discussed.
The theoretical basis is illustrated by the examples of the modern search systems, such as Google, Bing, Yahoo Search, Clusty, etc.

Outcomes

On completion of this module, the student should be able to
• Understand the principles used in the design of the modern search engines, especially with respect to the relevance ranking, indexing and crawling.
• Discuss the differences between the traditional text- and Web IR.
• Compare the algorithms available to perform relevance ranking on the Web.
• Understand the differences between classification and clustering and discuss their applications in IR domain.
• Explain the query expansion and reformulation methods.
• Understand the principles used in the evaluation of search engines.
• Be aware of the query optimization issues.

Recommended Literature

Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze, Introduction to Information Retrieval, Cambridge University Press. 2008.

Because this is a rapidly changing field, some of the newer literature may be announced during the lectures.

Recommended Prerequisite Knowledge

Basic understanding of database technologies. Nevertheless, this module is mostly self-contained and should not pose a problem even if no prior database knowledge is present.

Teaching Methods

slide presentation, home work, discussions

19 2.03 Cooperative Systems Technologies

Lecturer	Dr. Harrer, Andreas (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	2070
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Summer

Description

The module gives a technology-centered introduction to cooperation systems. The different types of these systems are discussed together with their technological implications. General design patterns, architectures and algorithms for building cooperative systems are presented and practically applied using state-of-art technologies in the field.

Outcomes

On successful completion of this module, the students have acquired the basic knowledge that is required for building "groupware" (internet based systems for supporting group communication and coordination). They know the main applications areas for cooperative systems and are able to use and critically review/compare libraries for building these systems.

Recommended Literature

Because this is a rapidly changing field, some of the newer literature may be announced during the lectures.

Recommended Prerequisite Knowledge

Principles of human-machine interaction, programming skills in Java

Teaching Methods

Beamer and multi-media presentation, individual homework, group homework, group discussions

20 2.04 Computer-Supported Cooperative Work

Lecturer	Dr. Harrer, Andreas (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	2065
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Winter

Description

The module presents concepts and principles of supporting group work using internet technologies. General theories and design principles of CSCW systems are illustrated using case studies of existing tools as examples. The course includes a discussion of evaluation techniques for CSCW systems.

Outcomes

On completion of this module, the students have learned the basic design principles for building CSCW systems. They know the central technological ways of supporting group interaction and they are able to evaluate and critically discuss groupware systems.

Recommended Literature

- Gross/Koch: Computer-Supported Cooperative Work, Oldenbourg

Because this is a rapidly changing field, some newer literature will be announced during the lectures.

Recommended Prerequisite Knowledge

Principles of human-machine interaction

Teaching Methods

Beamer and multi-media presentation, individual homework, group homework, group discussions

21 2.05 XML Databases and Semantic Web

Lecturer	Prof. Dr. Hartmann, Sven (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	2060
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Winter (biyearly)

Description

This course provides students with an insight into XML-based information management. It gives an introduction into state-of-the-art approaches to modeling and processing XML data. The course discusses query languages, query evaluation methods, integrity constraints, and DBMS support for XML. Furthermore, the relevance of XML for the Semantic Web is discussed. The course is accompanied by practical exercises.

Outcomes

On successful completion of the course students are able to explain and apply concepts and techniques used in XML data management, have acquired practical skills in XML data modelling and data processing, know computational and mathematical foundations of XML, and understand the importance of enhancing data on the web with meanings.

Recommended Literature

- Møller, Schwartzbach: XML and Web Technologies, Addison Wesley
- Melton, Buxton: Querying XML – XQuery, XPath and SQL/XML in Context, Morgan Kaufmann
- Yu: A Developer's Guide to the Semantic Web, Springer

Recommended Prerequisite Knowledge

The module presumes a prior understanding of data management concepts as, for example, acquired through an introductory module on databases at undergraduate level.

Teaching Methods

Beamer and multmedia presentation, group discussions, individual homework, group homework, practical exercises

22 2.06 Software Architectures of Distributed Systems

Lecturer	Prof. Dr. Rausch, Andreas (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	2055
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Summer

Description

This module covers the design process in the overall software development process. In this context important terms, roles, methods, and the process itself are introduced. Further the result of the design process, the software architecture, is focused. This module deals with view-based and UML-based specification of software architectures. As guidelines architectural patterns, standard architectures and solutions for technical aspects are introduced. Criteria, how to analyze and evaluate software architectures are discussed.

Outcomes

On successful completion of this module, the students are able to
- explain and apply the design process
- apply methods and description techniques
- understand solutions for technical aspects like transaction management or persistence
- design software architecture views based on UML
- analyse and rate software architectures
- apply architecture patterns
- explain standard architectures and solutions for example for persistence, transaction management, and workflow control

Recommended Literature

The literature will be announced and provided to the students in the lecture.

Recommended Prerequisite Knowledge

Basic Software Engineering, technologies for distributed applications, objectoriented programming, UML

Teaching Methods

Slide presentation, blackboard lecture, group homework, individual homework, discussion groups

23 2.07 Web Information Systems and Services

Lecturer	Prof. Dr. Hartmann, Sven (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	2050
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Summer (biyearly)

Description

This module gives a technology-centered introduction to data-intensive web information systems and services. Besides relevant concepts, techniques, standards, and policies, also advanced topics like transaction management and web-scale data management will be discussed.

Outcomes

On successful completion of the module students are able to explain basic concepts used in building and operating web information systems. They know central technological standards underlying data-intensive web information systems and services, understand architectural principles, and are able to evaluate and critically discuss such systems.

Recommended Literature

-Abiteboul et al.: Web Data Management, Cambridge University Press
-Alonso et al.: Web Services: Concepts, Architectures and Applications
-Kappel et al.: Web Engineering, Wiley
-Papazoglou: Web Services, Pearson
-Zhao et al: On the Spectrum of Web Scale Data Management, in Cloud Computing, CRC Press

Recommended Prerequisite Knowledge

The module presumes a prior understanding of data management concepts as, for example, acquired through an introductory module on databases at undergraduate level.

Teaching Methods

Beamer and multmedia presentation, group discussions, individual homework, group homework, practical exercises

24 2.08 Testing of Distributed Systems

Lecturer	Prof. Dr. Grabowski, Jens (Göttingen)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2045
Exam Type	Written or oral exam, graded
Exam Duration	Written (100 min) / Oral (25min)
Semester	Winter

Description

This module gives a broad overview on quality engineering, with particular emphasis on testing. After an introduction to quality engineering in general, all major methods for static and dynamic testing are introduced. Examples of these methods are: reviews, metrics, data and control flow analysis, coverage criteria for white-box-testing, equivalence class partitioning, error guessing, etc. Afterwards, the peculiarities of testing OO-Software are discussed. Especially for standards-based testing, the standardized test languages TTCN-3 and UML Testing Profile are introduced. Furthermore, tool support for testing (e.g., JUnit) is described. Finally, an overview of test management is given.

Outcomes

On completion of this module, the student
- understands the principles quality engineering.
- can apply the various techniques for quality engineering and test design for small and medium sized examples.
- is aware of strengths and flaws of different test methods.

Recommended Literature

Some of the newer literature will be announced during the lectures. Here are a few example books on the field:
Andreas Spillner, Tilo Linz, Hans Schäfer. Software Testing Foundations – A Study Guide for the Certified Tester Exam, 2nd edition. Rocky Nook, 2007.
Robert V. Binder. Testing Object-Oriented Systems: Models, Patterns, and Tools. Addison Wesley, 1999
Boris Beizer. Black-Box Testing. Jon Wiley & Sons Inc., 1995.
Paul Baker, Zhen Ru Dai, Jens Grabowski, Oystein Haugen, Ina Schieferdecker, Clay Williams. Model-Driven Testing – Using the UML Testing Profile. Springer Verlag, 2007
Glenford J. Myers. The Art of Software Testing. Jon Wiley & Sons Inc., 2004.

Recommended Prerequisite Knowledge

none

Teaching Methods

The lecture will be in form of slide presentations combined with whiteboard. The exercise include lab exerices, individual as well as group work including homework. The solutions of the exercises need to be presented by the students. Four excercises require personal attendence of the students in Göttingen.

25 2.09 Principles of Grid- and Cloud-Computing

Lecturer	Prof. Dr. Grabowski, Jens (Göttingen)
Weekly Composition	1L+1S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	2040
Exam Type	Written or oral exam, graded
Exam Duration	Written (100 min) / Oral (25min)
Semester	Winter

Description

This module presents concepts, principles and existing implementations of grid and cloud systems. Grid technology is explained by presenting its architecture and also different grid middlewares. Main features of a middleware such as resource, job, data, information and service management are discussed. Also security and high level services such as scheduling, planning and workflow management are considered. Furthermore, main topics of grid computing such as accounting, billing, knowledge and semantics, and sustainability are presented. Afterwards, cloud computing is introduced and its relation to grid computing is discussed. This also includes the cloud architecture and virtualization principles. After a theoretical presentation of these concepts, they are exemplified by practical examples from the grid and cloud communities.

Outcomes

On completion this module, the students have basic knowledge of grid computing, how it is realized and when to use it. They know all concepts and principles around the grid computing technology including their purposes and their realizations. In addition, the students understand cloud computing including its principles and can differentiate it to a grid system.

Recommended Literature

Ian Foster, Carl Kesselman: “The Grid 2: Blueprint for a New Computing Infrastructure”, Morgan Kaufmann, Amsterdam ; Boston, 2004.

Frédéric Magoulès: “Introduction to Grid Computing”, CRC Press, Boca Raton, 2009

Rajkumar Buyya, James Broberg, Andrzej M. Goscinski: "Cloud Computing: Principles and Paradigms", Wiley Series on Parallel and Distributed Computing, 2011

Recommended Prerequisite Knowledge

none

Teaching Methods

The lecture will be in form of slide presentations combined with whiteboard. The exercise require independent research of the students, who need to give a presentation about a specific research topic of cloud computing.

26 2.10 Distributed Information Storage and Management

Lecturer	Prof. Dr. Yahyapour, Ramin (Göttingen)
Weekly Composition	2L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 108
Exam ID	2035
Exam Type	Written or oral exam, graded
Exam Duration	Written (90 min) / Oral (25min)
Semester	Summer

Description

This module provides a comprehensive understanding of the varied storage infrastructure components in classic and virtual environments. It enables participants to make informed decisions in an increasingly complex IT environment. It provides a strong understanding of underlying storage technologies and prepares participants for advanced concepts, technologies, and products. Participants will learn the architectures, features, and benefits of intelligent storage systems; storage networking technologies such as FC SAN, IP SAN, NAS, and object-based and unified storage; business continuity solutions such as backup and replication; the increasingly critical area of information security and management, and the emerging field of Cloud computing. This unique, open course focuses on concepts and principles which are further illustrated and reinforced with EMC product examples.

Outcomes

Upon successful completion of this course, participants are able to:

• evaluate storage architectures and key data center elements in classic, virtualized, and cloud environments
• explain physical and logical components of a storage infrastructure including storage subsystems, RAID, and intelligent storage systems
• describe storage networking technologies such as FC SAN, IP SAN, FCoE, NAS, and object-based and unified storage
• articulate business continuity solutions—backup and replication, and archive for managing fixed content
• describe information security requirements and solutions, and identify parameters for managing and monitoring storage infrastructure in classic, virtualized, and cloud environments

Recommended Literature

EMC: Information Storage and Management: Storing, Managing, and Protecting Digital Information, John Wiley & Sons; 2nd edition, 2012

Ulf Troppens (Autor), Rainer Erkens (Autor), Wolfgang Mueller-Friedt (Autor), Rainer Wolafka (Autor), Nils Haustein (Autor): Storage Networks Explained: Basics and Application of Fibre Channel SAN, NAS, iSCSI,InfiniBand and FCoE, John Wiley & Sons; 2nd edition, 2009

Recommended Prerequisite Knowledge

none

Teaching Methods

The lecture will be given in form of a slide presentation in combination with the white board. The exercise will be in form of group homework, which needs to be presented to all participants.

27 2.12 Application Development with Web Services

Lecturer	Prof. Dr. Schneider, Kurt (Hannover)
Weekly Composition	6P
ECTS	6
Working Hours (presence/self-study)	84 / 66
Exam ID	2025
Exam Type	Ungraded
Exam Duration	By active participation
Semester	Winter

Description

In this module, students will form a development team to create a service-oriented application with a web-based client. In the first phase of the project, each student will teach the other participants about a certain technology related to service orientation. The second phase consists of 3 to 4 iterations of actual development. The application will support an actual business process present at the university, automating tasks as much as possible. After each iteration, a ready-to-use version of the application should be available.

Outcomes

On completion of this module, the student have gained the competency to
- prepare and give a presentation about a technical topic
- develop software in a team
- develop software iteratively
- understand the concepts of service orientation
- assess the pros and cons of the different technical approaches to service orientation, depending on the task at hand
- develop service oriented applications.

Recommended Literature

On most topics, documentation is available online for free, for which recommendations will be given during the course. For conceptual preparation, the following two books are good examples.
Nicolai Josuttis: SOA in Practice: The Art of Distributed System Design; O'Reilly 08/2007
Zimmermann, Tomlinson, Peuser: Perspectives on Web Services: Applying SOAP, WSDL and UDDI to Real-World Projects; Springer 09/2005

Recommended Prerequisite Knowledge

none

Teaching Methods

practical exercises, group work, presentation

28 2.13 Semantic Web

Lecturer	Prof. Dr. Nejdl, Wolfgang (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2020
Exam Type	Written or oral exam, graded
Exam Duration	Written (60 min) / Oral (30 min)
Semester	Winter

Description

The lecture and accompanying exercise gives in introduction to the ideas of the Semantic Web. Markup Languages (HTML, SGML, XML) & friends (XPATH, XQUERY, XSL, XSLT, XSL-FO, etc) are the basics. Then, the architecture of the Semantic Web is investigated with the modeling language (Resource Description Framework), ontologies and ontology languages, rules, and rule-based languages. Foundation of logic - as required for the use in the Semantic Web – is taught. Applications of information systems in the Semantic Web, actual topics from W3C and from conferences are covered in the lecture as well.

Outcomes

The students know the idea and architecture of the Semantic Web, and have working knowledge about query- ,transformation-, description- and ontology languages and formalisms. They know relevant Semantic Web applications, and have learned to critically analyze approaches and trends.

Recommended Literature

Grigoris Antoniou, Frank van Harmelen: A Semantic Web Primer. Covers the topics Semantic Web Vision, XML, RDF, Web Ontology Languages, Logic and Inference, Applications, Ontology engineering. Some information online: http://www.ics.forth.gr/isl/swprimer/
W3Schools online tutorials http://www.w3schools.com/
W3C Semantic Web Activity http://www.w3.org/2001/sw/
Further literature will be announced with each lecture.

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

29 2.14 Web Science

Lecturer	Prof. Dr. Nejdl, Wolfgang (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2015
Exam Type	Written or oral exam, graded
Exam Duration	Written (90 min) / Oral (25min)
Semester	Summer

Description

Web Science embraces the study of the Web as a vast information network of people and communities. It also includes the study of people and communities using the digital records of user activity mediated by the Web. An understanding of human behavior and social interaction can contribute to our understanding of the Web, and data obtained from the Web can contribute to our understanding of human behavior and social interaction. This module gives an overview over the disciplines relevant to Web Science, and discusses in details the aspects relevant to computer sciences.

Outcomes

On completion of this module, the student has a good overview over Web Science as an interdisciplinary research area, and is familiar with current computer science related research in this context, including both recent results as well as research methods used to obtain these results.

Recommended Literature

The course will be based on a selected set of scientific articles covering Web Science, available online. To get an impression of the topics and research covered in this module, please check the latest Proceedings of the ACM Web Science Conference, available in the ACM Digital Library.

Recommended Prerequisite Knowledge

Foundations of Information Retrieval

Teaching Methods

slide presentation, home work, presentations and discussions

30 2.15 Advanced Topics in Web Science

Lecturer	Prof. Dr. Nejdl, Wolfgang (Hannover)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	2010
Exam Type	Oral Presentation
Exam Duration	Presentation (30-40 min)
Semester	Summer and Winter

Description

The seminar covers research topics in Web Science, based on the work of the participating students and/or scientific research performed elsewhere on these topics. Each student gives a presentation about specific research performed, focusing on results, methods used, background literature, and presentation.

Outcomes

The student is able to present and discuss his/her own research, or research work performed elsewhere, as well as get an overview of other research in the area of Web Science. Students will learn scientific presentation skills, and are able to discuss in detail specific research work performed, including results, algorithms, evaluation, and research methods in general.

Recommended Literature

Literature will vary, but check the latest Proceedings of the Web Science and the World Wide Web Conference to get an impression of the topics covered.

Recommended Prerequisite Knowledge

Foundations in Information Retrieval and/or Web Science

Teaching Methods

homework, presentation, discussion

31 2.17 Data Warehousing and Data Mining Techniques

Lecturer	Prof. Dr. Balke, Wolf-Tilo (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2005
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

This module will give a broad overview over all methods that are necessary for building and using data warehouses in large-scale applications. Besides typical techniques for warehouse design, indexing, and online analytical processing (OLAP), also advanced data mining techniques like frequent item set mining and association rules are covered in the lecture.

Outcomes

On completion of this module, the students know the basic designs, theoretical foundations, and practical applications of data warehouses. Also, they have deep understanding of employed data structures and algorithms.
This enables students to identify and recognize typical data warehouse problems in common business cases. They are able to assess and analyse these problems, and based on their results and their technical proficiency with common tools, techniques, and concepts, they are able to develop requirements and designs for suitable data warehouse solutions. Furthermore, the students are aware of typical challenges arising from the introduction of data warehouse solutions, and are have an understanding of the impact of these solutions on a company's workflows.
Also, the students learn to deal with scientific source material by working with state-of-the art scientific publications which go far beyond typical capabilities of currently available tools.

Recommended Literature

-W. Inmon: Building the Data Warehouse, Wiley, ISBN 0-7645-9944-5
-R. Kimball & M. Ross: The Data Warehouse Toolkit, Wiley, ISBN 0-471-20024-7
-Erik Thomsen: OLAP Solutions, Wiley, ISBN 0-471-40030-0
-Robert Wrembel & Christian Koncilia: Data Warehouses and OLAP, IRM Press, ISBN 1-59904364-5

Recommended Prerequisite Knowledge

Prior knowledge in basic database technology (e.g. SQL, relational algebra, etc) is required.

Teaching Methods

slide presentation, home work, discussions

32 2.18 Advanced Topics in Information Systems

Lecturer	Prof. Dr. Balke, Wolf-Tilo (Braunschweig)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	2085
Exam Type	Oral Presentation
Exam Duration	25min
Semester	Summer and Winter

Description

In this seminar, students are familiarized with scientific literature research, and learn to prepare and give scientific presentations.
Each semester, a topic within the field of information systems is selected and the students will be assigned a specific aspect of that topic. Then, each student is required give a comprehensive 30-minute presentation on the chosen aspect of that topic. The focus of this module is heavily on identifying and discussing the relevant literature, compiling a clear and understandably presentation of a complex topics, and general rhetoric skills.
In the first few weeks, there will be an extensive introduction into helpful techniques and best-practises. Then, each week, one of the students will present his/her topic, followed by an extensive group discussion. Students will be provided with video tapes of their own presentation for further analysis.
Active participation in the discussion is mandatory.

Outcomes

Students will learn the basics of scientific presentation, rhetoric skills, and literature-based scientific research in a guided environment.
Students are able to competently plan a scientific talk, and to perform the required preparations. Furthermore, they will be aware of their personal rhetoric strength and weaknesses.

Recommended Literature

Varies every semester depending on topic. As this module is closely focused on mastering basics of scientific literature research and rhetoric, the recommended literature is mainly comprised of topic-relevant high-ranking scientific conference or journal publications.

Recommended Prerequisite Knowledge

Prior knowledge in basic database technology (e.g. SQL, relational algebra, etc) is recommended, but not strictly necessarily.

Teaching Methods

slide presentation, home work, discussions

33 2.19 Personalization and User Modeling

Lecturer	Dr. Herder, Eelco (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2006
Exam Type	Written exam, graded
Exam Duration	60 minutes
Semester	Summer

Description

This course will provide the foundations for user modeling and personalization. We discuss basic methods for user observation, the most common types of user models and a wide range of personalization techniques. Building upon this, we will specifically look at state-of-the-art content-based and collaborative recommendation techniques. Specific attention will also be given to evaluation techniques and relevant theories from the field of human-computer interaction.

Outcomes

After this course, students can apply HCI-techniques for identifying user needs and building user models; they know about the most important personalization and recommendation techniques and they can use these techniques in practice; they are able to assess personalization aspects in computer systems.

Recommended Literature

P. Brusilovsky, A. Kobsa und W.Nejdl: "The Adaptive Web: Methods and Strategies of Web Personalization", Springer 2007
Online references and papers will be provided during the lecture

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

34 2.20 Algorithms for Internet Applications

Lecturer	Prof. Dr. Nejdl, Wolfgang (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2041
Exam Type	Written exam, graded
Exam Duration	60 min
Semester	Winter

Description

Internet and World Wide Web are changing our world, this core course provides the necessary background and methods for the design of central applications of the Internet, in particular in support of electronic commerce. After an introduction into Internet technology the following topics are addressed: information retrieval in the net, structure and functioning of search engines, secure communication, electronic payment systems and digital money, and - if time permits - security architectures(firewalls), data compression, distributed computing on the Internet.

Outcomes

The student has an overview over the main concepts of the Internet and the World Wide Web, and about background and methods necessary for electronic commerce.

Recommended Literature

All course materials are provided online.

Recommended Prerequisite Knowledge

none

Teaching Methods

slide presentation, exercises

35 2.21 Selected Topics in Database Systems

Lecturer	Prof. Dr. Hartmann, Sven (Clausthal)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	2031
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (30-45min)
Semester	Winter

Description

This seminar is dedicated to the discussion of trends and recent advances in the field of database and information systems. You are provided exposure to topics beyond the standard curriculum. Example topics covered in past offerings include: database as a service, NoSQL databases, spatial databases, embedded databases, and data streams.

In the beginning of the semester, instruction is given in how to review research literature, devise research talks and essays, find relevant background literature, and practise presentation skills.

For the seminar you will read a research paper, prepare an oral presentation emphasising the research goals, methods, and solutions proposed in the paper, and deliver the presentation in class. For your presentation you will receive feedback from the lecturer and your peers. Taking into account the feedback you will then write a essay reviewing the chosen paper and elaborating the subject by gathering more background information. You will also attend the presentations by your peers, and participate actively in class discussions that accompany their presentations.

Outcomes

On successful completion of the module, you will be able to read and analyse research literature, identify research questions and strategies used for their settlement, review research contributions, communicate effectively through technical presentations and written essays, critique presentations, and engage in research-oriented discussions.

Recommended Literature

Varies every semester depending on topic. As the seminar has its focus on current directions in research, the recommended literature will mainly consist of recent articles from topic-specific international conferences or journals.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of data management concepts as, for example, acquired through an introductory module on databases at undergraduate level.

Teaching Methods

Student presentations, group discussions

36 2.22 Information Systems Security

Lecturer	Prof. Dr. Hartmann, Sven (Clausthal)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	2032
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (30-45min)
Semester	Summer

Description

This seminar is dedicated to the discussion of trends and recent advances in the field of database and information systems security. You are provided exposure to topics beyond the standard curriculum.

In the beginning of the semester, instruction is given in how to review research literature, devise research talks and essays, find relavant background literature, and practise presentation skills.

For the seminar you will read a research paper, prepare an oral presentation emphasising the research goals, methods, and solutions proposed in the paper, and deliver the presentation in class. For your presentation you will receive feedback from the lecturer and your peers. Taking into account the feedback you will then write a essay reviewing the chosen paper and elaborating the subject by gathering more background information. You will also attend the presentations by your peers, and participate actively in class discussions that accompany their presentations.

Outcomes

On successful completion of the module, students will be able to read and analyse research literature, identify research questions and strategies used for their settlement, review research contributions, communicate effectively through technical presentations and written essays, critique presentations, and engage in research-oriented discussions.

Recommended Literature

Biskup: Security in Computing Systems, Springer

As the seminar has its focus on current directions in research, the recommended literature will mainly consist of recent articles from topic-specific international conferences or journals.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of data management concepts as, for example, acquired through an introductory module on databases at undergraduate level.

Teaching Methods

Student presentations, group discussions

37 2.23 Experience and Knowledge Management in Software Engineering

Lecturer	Prof. Dr. Schneider, Kurt (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2033
Exam Type	Written exam, graded
Exam Duration	60 min written
Semester	Winter (biyearly)

Description

Foundations and visions of knowledge management in general, and within software engineering. Relevance of experience for improvement. Informal, semi-formal and formalized representations for experiences and knowledge in SE (from MindMaps over RDF, RDFS to Ontologies). Selected tools for knowledge handling and model-driven software development (such as Protégé, XSLT, Code generator).

Outcomes

Students know the basics of systematic learning from experience and knowledge in software engineering. They are able to identify appropriate application areas within software engineering and apply the principles. They are able to apply model-based generation to knowledge issues in software development.

Recommended Literature

Schneider, Kurt (2009): Experience and Knowledge Management in
Software Engineering. Springer, Berlin.

Recommended Prerequisite Knowledge

Java

Teaching Methods

Slide presentation, exercises, discussions

38 2.24 Parallel Computing

Lecturer	Prof. Dr. Yahyapour, Ramin (Göttingen)
Weekly Composition	2L+2E
ECTS	6
Working Hours (presence/self-study)	56 / 94
Exam ID	2034
Exam Type	Written exam, graded
Exam Duration	120
Semester	Winter

Description

This module covers advanced parallel computing topics, starting with an overview of programming models as used for universal systems (like MIPS) as well as special purpose machines.
Next, the principles of micro-processor architectures are introduced, putting the focus on pipelining and related methods to increase execution performance.
The third block of this lecture then covers compute systems with multiple processors/computational units, including multi-threading, multi-core systems, and clusters.

Outcomes

Completing this module, students acquire:
- understanding of the theoretical foundations of parallel computing systems
- principles of programming models, challenges, and approaches to solutions for multi-processor and multi-core systems
- insights into parallel computing architectures, including design principles, obstacles, and existing implementations

Recommended Literature

- Peter S. Pacheco: Parallel Programming, Morgan Kaufman, 2011.
- Thomas R., Gudula R.: Parallel Programming for Multicore and Cluster Systems, Springer, 2. edition 2010.
- Hennessy, John L., Patterson, David A.: Computer Architecture - A Quantitative Approach, Morgan Kaufman, 3. edition 2003.
- Culler, David E., Singh, Jaswinder Pal, Gupta, Anoop: Parallel Computer Architecture: A Hardware/-Software Approach, Morgan Kaufman, 1999.
- Hwang, Kai: Advanced Computer Architecture: Parallelism, Scalability, Programmability, McGraw-Hill, 1993.
- Adve, Sarita V., Gharachorloo, Kourosh: Shared Memory. Consistency Models: A Tutorial, DIGITAL, WRL Research Report 95/7.

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

39 2.25 Service Computing

Lecturer	Prof. Dr. Yahyapour, Ramin (Göttingen)
Weekly Composition	2L+2E
ECTS	5
Working Hours (presence/self-study)	56/94
Exam ID	2036
Exam Type	Written or oral exam, graded
Exam Duration	Written 120 min / Oral 30 min
Semester	Summer

Description

Service-oriented infrastructures are the backbone of modern IT systems. They pool resources, enable collaboration between people, and provide complex services to end users. Everybody who uses today's web applications such as Facebook, Google, or Amazon implicitly relies on sophisticated service-oriented infrastructures. The same is true for users of mobile devices such as tablet computers and smart phones, which provide most of their benefits leveraging services such as Dropbox, Evernote, and iTunes. These examples and many more services build on sophisticated service oriented infrastructures.
The key challenges of service oriented infrastructures are related to scaling services. More specifically large service oriented infrastructures require scalability of IT management, programming models, and power consumption. The challenges to scale services lie in the inherent complexity of hardware, software, and the large amount of user requests, which large-scale services are expected to handle. This module teaches methods that address and solve those challenges in practice. Key aspects of the module are the management of IT infrastructures, the management of service landscapes, and programming models for distributed applications. IT management covers Cloud computing, and the virtualisation of computing, storage, and network resources. Cloud computing in specific is covered by the discussion of production-grade infrastructure-as-service and platform-as-a-service middlewares. IT management is covered by the discussion of deployment models, service level agreements, and security aspects. Programming models are covered by discussing
RESTful and SOAP web services, MapReduce, and OSGi.
Both, lectures and exercises, keep a close connection to the practical application of the discussed topics. The practical value of service-oriented infrastructures is highlighted in the context of enterprises as well as in the context of science. The methods taught in this module benefit from the lecturers' experiences at GWDG and thus provide exclusive insights into the topic. After successfully attending this modules students will understand the most important aspects to design, implement, and manage internet-scale service oriented infrastructures.

Outcomes

Successfully completing the module, students
- understand basic web technologies (transfer protocols, markup languages, markup processing, RESTful and SOAP web services),
- understand virtualisation technologies (server, storage, and network virtualisation),
- understand Cloud computing (standards, APIs, management, service layers),
- understand security mechanisms for distributed systems (authentication,

authorisation, certificates, public key infrastructures),
- understand data services (sharing, management, and analysis),
- understand Big Data technology (MapReduce).

On completion of this module students will have a good understanding of the fundamental and up-to-date concepts used in the context of service-oriented infrastructures. This basic knowledge can be leveraged by students to design, implement, and manage service-oriented infrastructures by themselves.

Recommended Literature

- Ingo Melzer: Service-orientierte Architekturen mit Web Services. 2010.
- Jörg Schwenk: Sicherheit und Kryptographie im Internet: Von sicherer E-Mail bis zu IP-Verschlüsselung. Vieweg+Teubner, 2010 (S.1-28)
- Christian Baun, Marcel Kunze, Jens Nimis et al.: Cloud Computing: Web-basierte dynamische IT-Services. Springer, 2009
- Tom White: Hadoop: The Definitive Guide. O'Reilly Media, Inc., 2010

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

40 2.26 Project and Quality Management in Software Systems Engineering

Lecturer	Prof. Dr. Rausch, Andreas (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	2037
Exam Type	Oral exam, graded
Exam Duration	Oral (25 min)
Semester	Summer

Description

The module covers the following topics:
- definition of project management and quality assurance
- basic terms of software project implementation
- models (process and quality models) as basis for systematic project management / quality assurance
- basic concepts of project and process management
- basic concepts of measurement and evaluation
- techniques/methods/tools to support project management and quality assurance
- examples of projects from practice

Outcomes

Students will acquire and practice the following competencies:

Conceptual knowledge of professional standards for Project Management, Process Improvement and Quality Management, in particular
PMBOK
CMMI
Knowledge of fundamental ideas, e.g. Plan-Do-Check-Act, Continuous process improvement, maturity levels, statistical process control
Knowledge about the relationship between these standards and software engineering process models, e.g. V-Modell and RUP
Practical application of this knowledge, in particular PMBOK- and CMMI-process area knowledge to case studies
Application of the maturity level concept of CMMI to projects and to organizations

After attending the lecture, students will be able to competently use Project Management standards and the CMMI model to professionally set up and manage an effective software development project.

On a voluntary basis, students can get the official CMMI-Institute-certificate Ïntroduction to CMMIäfter passing the exam.

Recommended Literature

Pankaj Jalote: Software Project Management in Practice Addison-Wesley Professional, 2002
Hughes, Cotterrell: Software Project Management, McGraw-Hill Publishing Co., 2002

Project Management Institute PMI (2013): A guide to the project management body of knowledge. (PMBOK guide). 5. ed. PMI, Newtown Square, PA, USA.

Fred Brooks: The mythical man-month. Essays in Software Engineering. Addison-Wesley 1995.
Mary Beth Chrissis, Mike Konrad, Sandy Shrum: CMMI for Development V1.3 - 3rd edition. Guidelines for Process Integration and Product Improvement. SEI Series in Software Engineering, Addison Wesley 2011.
Software Engineering Institute / CMMI-Institute: Ïntroduction to CMMI-for-Development v.1.3"class materials, Carnegie Mellon University, 2013.
Suzanne Garcia, Richard Turner: CMMI Survival Guide. Just Enough Process Improvement. SEI Series in Software Engineering, Addison Wesley 2006.
Michael West: Real Process Improvement using the CMMI. Auerbach Publishers 2004.
Paul E. McMahon: Integrating CMMI and Agile Development. SEI Series in Software Engineering, Addison Wesley 2011.

Further literature will be announced in the lectures.

Recommended Prerequisite Knowledge

Basic Software Engineering

Teaching Methods

Slide presentation, blackboard lecture, group homework, individual homework, discussion groups

Some parts will be made available as Video recording.

41 2.27 Formal Concept Analysis

Lecturer	Prof. Dr. rer. nat. Jäschke, Robert (Hannover)
Weekly Composition	2L+1E
ECTS	4
Working Hours (presence/self-study)	40 / 80
Exam ID	2027
Exam Type	Oral exam, graded
Exam Duration	30 Minutes
Semester	periodically, according to student demand and staff specialisms

Description

Formal Concept Analysis deals with the extraction and exploration of concepts and concept hierarchies from data. The methods presented in this module are suitable for data analysis and knowledge acquisition. In particular, a structuring of the concepts using (specialization) hierarchies, different visualization techniques and several algorithms for exploring the attribute space are presented. Topics of the module are:
- concept lattices
- conceptual scaling
- closure systems, the NextClosure algorithm and the TITANIC algorithm
- implications and the stem base
- attribute exploration
- iceberg concept lattices and association rules
- triadic formal concept analysis, including the TRIAS algorithm
- applications of formal concept analysis

Outcomes

On completion of this module, the students will be able to
- understand concept lattices
- interpret (scale) multi-valued contexts as one-valued contexts
- read and understand concept lattice diagrams
- compute a concept lattice from a formal context
- draw a concept lattice diagram
- calculate implications of a formal context
- infer implications
- calculate pseudo-intents and the stem basis
- understand and apply the algorithms NextClosure, TITANIC, and TRIAS
- read and understand diagrams of triadic formal concept lattices
- know applications of formal concept analysis

Recommended Literature

- B. Ganter, R. Wille: Formal Concept Analysis: Mathematical Foundations. Springer, 1999.
- Computing iceberg concept lattices with TITANIC. G. Stumme, R. Taouil,Y. Bastide, N. Pasquier and L. Lakhal. Data & Knowledge Engineering 42(2):189-222, 2002.
- Discovering Shared Conceptualizations in Folksonomies. R. Jäschke, A. Hotho, C. Schmitz, B. Ganter and G. Stumme. Web Semantics: Science, Services and Agents on the World Wide Web 6(1):38-53, 2008.

Recommended Prerequisite Knowledge

The module presumes elementary mathematical foundations as, for example, acquired through an introductory module on mathematics at undergraduate level.

Teaching Methods

slide presentation, blackboard lecture, group work, individual homework

42 2.28 Machine Learning

Lecturer	Dr.rer.nat. Diaz-Aviles, Ernesto (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2038
Exam Type	Written exam, graded
Exam Duration	90 min
Semester	Winter

Description

Machine learning is the field of study of getting computers to learn and act without being explicitly programmed. Machine learning is widely used in science, industry, government and business. In the past decade, machine learning has provided feasible and cost-effective means for web search, computer vision, smart robots, speech recognition and other areas of AI.
This course provides a broad introduction to machine learning, data mining, and statistical pattern recognition.
Most of the class will be focused on supervised learning, which can be considered the most mature and widely
used type of machine learning. We will also explore the most popular Unsupervised learning techniques: clustering and dimensionality reduction. Furthermore, during the course, we will discuss best practices in machine learning and provide practical advice for applying learning algorithms.
In the class projects you will build your own implementations of machine learning algorithms and apply them
to problems like text recognition, spam filtering and recommender systems. This will give you the insights and
tools needed to become an expert in this exiting field.

Outcomes

Upon completion of the course, students will be able to:
1. Understand the fundamentals of machine learning, data mining, and statistical pattern recognition
2. Implement, debug, and evaluate state-of-the-art machine learning algorithms
3. Correctly apply machine learning algorithms to problems like text recognition, spam filtering and recommender systems

Recommended Literature

We will provide lecture notes to cover the material. There is no single book that cover every aspect of the
course. Some of the sources include:
- Christopher M. Bishop. Pattern Recognition and Machine Learning. Springer-Verlag, 2006
- R.O. Duda, P.E. Hart, and D.G. Stork. Pattern Classification. John Wiley & Sons, 2001
- Thomas M. Mitchell. Machine Learning. McGraw-Hill, 1997

Recommended Prerequisite Knowledge

The main prerequisite for this class is basic knowledge of programming, that is, we assume that you know how
to program in at least one programming language.
Some previous exposure to probability, statistics, linear algebra, calculus and/or logic is useful but not essential. We will cover the basic concepts and go over the math concepts you need in the first couple of weeks.

Teaching Methods

Slide presentations, exercises, discussions, homework and programming assignments

43 2.29 Advanced Topics in Knowledge Engineering

Lecturer	Dr. Wiese, Lena (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	2042
Exam Type	Written Report and Oral Presentation
Exam Duration	30-40 min
Semester	Winter

Description

This seminar module covers selected topics in the area of Knowledge Engineering (for example, information modeling, knowledge representation, logical data security, or intelligent information systems). Students will be assigned a topic on which they have to prepare a written essay that has to cover the main aspects of the assigned topic. Moreover, students have to prepare a set of presentation slides and give a talk in class.

Outcomes

On completion of this module, students are able to read and understand scientific articles, write an essay on an advanced topic in the area of Knowledge Engineering, give a scientific talk and actively participate in discussions.

Recommended Literature

Recent research articles in the area of Knowledge Engineering as announced in the first meeting.

IEEE Transactions on Knowledge and Data Engineering

Journal of Intelligent Information Systems

Recommended Prerequisite Knowledge

Basic knowledge in relational database technology (like SQL) is recommended, but not mandatory.

Teaching Methods

Slide presentations, home work, discussions

44 2.30 Advanced Topics in NOSQL Databases

Lecturer	Dr. Wiese, Lena (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	2043
Exam Type	Written Report and Oral Presentation
Exam Duration	30-45 min
Semester	Winter

Description

This seminar module covers selected topics of NOSQL databases like graph databases, object databases, XML databases, key-value stores, column-based databases or advanced concepts of distributed data management.
Students will be assigned a topic on which they have to prepare a written essay that has to cover the main aspects of the assigned topic. Moreover, students have to prepare a set of presentation slides and give a talk in class.
As an optional practical part, students can report on the installation and handling of one selected database system.

Outcomes

On completion of this module, students are able to read and understand scientific articles, write an essay on an advanced database topic, give a scientific talk and actively participate in discussions.

Recommended Literature

Recent research articles in the area of non-relational data management as announced in the first meeting.

Eric Redmond and Jim R. Wilson: Seven Databases in Seven Weeks, O'Reilly, 2012

Stefan Edlich, Achim Friedland, Jens Hampe, Benjamin Brauer, Markus Brückner: N*SQL, Hanser-Verlag, 2011

Recommended Prerequisite Knowledge

Basic knowledge in relational database technology (like SQL) is recommended, but not mandatory.

Teaching Methods

Slide presentations, home work, discussions

45 2.31 NOSQL Databases

Lecturer	Dr. Wiese, Lena (Göttingen)
Weekly Composition	3L + 1E
ECTS	6
Working Hours (presence/self-study)	56 / 124
Exam ID	2039
Exam Type	Written or oral exam, graded
Exam Duration	Written (90 min) or Oral (25min)
Semester	Summer

Description

This course focuses on how to store arbitrary documents, objects of programming languages, XML data and graphs in native databases; hence, the lecture covers graph databases, object databases, XML databases, key-value stores, and column-based databases and gives a comparison to storing these data in relational databases. Getting to know novel requirements for database management systems like flexible update and query behavior are further topics of the lecture as well as concepts of distributed data management.

Outcomes

On completion of this module, students are able to present concepts, data models and storage mechanisms of the different NOSQL databases and explain their differences to the relational model. Students show basic knowledge of NOSQL query languages and access models and are able to explain concepts of distributed database systems.

Recommended Literature

Eric Redmond and Jim R. Wilson: Seven Databases in Seven Weeks, O'Reilly, 2012

Stefan Edlich, Achim Friedland, Jens Hampe, Benjamin Brauer, Markus Brückner: N*SQL, Hanser-Verlag, 2011

Recommended Prerequisite Knowledge

Basic knowledge in relational database technology (like SQL) is recommended, but not mandatory.

Teaching Methods

Slide presentation, home work, discussions

46 2.32 Advanced Methods of Information Retrieval

Lecturer	Dr. Demidova, Elena (Hannover)
Weekly Composition	2L + 1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	2090
Exam Type	Oral exam, graded
Exam Duration	30 min
Semester	Summer

Description

In this module we introduce advanced methods and algorithms of Information Retrieval for structured and semi-structured data (such as relational databases, XML and RDF). The topics of the course include data structures, ranking methods and efficient algorithms that enable end users to effectively obtain the most relevant search results from structured, heterogeneous and distributed data sources. Furthermore, we will study the corresponding evaluation techniques as well as novel applications.

Outcomes

On completion of this module, the student should be able to: Discuss the differences between the text- and structured IR. Understand the principles used in the modern search systems for structured data, especially with respect to the indexing, query interpretation and relevance ranking. Understand the differences between data-based and schema-based query interpretation. Explain query refinement and diversification methods for structured data. Compare the algorithms available to perform relevance ranking of structured search results. Understand the principles used in the evaluation of structured search results. Become familiar with Linked Open Data. Understand techniques for federated search and schema mapping and. Become familiar with current search applications.

Recommended Literature

Jeffrey Xu Yu, Lu Qin, Lijun Chang. Keyword Search in Databases. Synthesis Lectures on Data Management. Morgan & Claypool Publishers. 2009.

In addition, current research articles will be provided during the lecture.

Recommended Prerequisite Knowledge

It is recommended that participants complete the course "Foundations of Information Retrieval"prior to attending this course. Basic knowledge of relational databases is recommended.

Teaching Methods

Lectures, Presentations, Exercises.

47 2.33 Social Network Analysis

Lecturer	Dr. Siersdorfer, Stefan (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42/83
Exam ID	2091
Exam Type	Written or oral exam, graded
Exam Duration	Written (90min) / Oral (25min)
Semester	Summer

Description

Social networks consist of persons, companies, and, more general, entities that can be interconnected in various ways. Analyzing the characteristics of such networks can help to gain a deeper understanding of sociological, political, and economic processes. Results of social network theory have implications that go beyond networks of people and also involve technical environments such as electrical power grids, road networks, and the internet. In this course we study the processes involved in the formation of networks and communities, information propagation and epidemics, and strategic decision making in networks.

Outcomes

The objectives of this course are the following:
- Providing an understanding of formation, diffusion, and strategic decision making in social networks
- Enabling a better understanding of real world phenomena in politics, society, and the World Wide Web in terms of the underlying networks
- Providing models that allow us to reason about networks and make predictions about different aspects of network dynamics
- Introduction of metrics for characterizing and quantifying different aspects of social networks , and interpretation of these metrics.
- Introduction of software tools that allow for visualizing and analyzing real world datasets on social networks

Recommended Literature

David Easley and Jon Kleinberg,
Networks, Crowds, and Markets: Reasoning About a Highly Connected World,
Cambridge University Press, 2010

Recommended Prerequisite Knowledge

basic knowledge of graphs and probability theory

Teaching Methods

Lectures, Presentations, Exercises.

48 2.34 Temporal Information Retrieval

Lecturer	Dr. Anand, Avishek (Hannover)
Weekly Composition	2L + 1E
ECTS	5
Working Hours (presence/self-study)	42/83
Exam ID	2044
Exam Type	Written or oral exam, graded
Exam Duration	Written(120 min) /Oral (25-30 mins)
Semester	Winter

Description

In the past decade, the Web has evolved in many aspects, such as, its size, content, and usage. With the growing volumes of and reliance on digital documents on the Web, there is a clear need for better information retrieval (IR) approaches that keep relevant information accessible, available, and meaningful over time. In the past decade, time-aware approaches to information retrieval have become interesting, emerging topics and shown that the time dimension affects search performance. In other words, it has been shown that taking the time dimension into account can improve search performance over traditional (non time-aware) IR approaches.

In this course, in the first place, aims to introduce students to the general and wide topic of Web evolution, and then pinpoint a number of issues that is related to temporal aspects of search and IR. We plan to start with an overview of seminal works that shed light on the evolution of Web within time. Next, we will focus on the impacts of this evolution on search and we will essentially focus on indexing of versioned document collections and time-aware retrieval and ranking. We will discuss evolution of search results, and wrap up the course with a review of some recent applications on mining and analytics on temporal web collections.

Outcomes

The course will teach the students the foundations of temporal analysis and retrieval techniques. The students will additionally understand how a temporal search engine works and the systems issues associated with building a search engine.

Recommended Literature

Papers and Book chapter to be provided during the lecture

Recommended Prerequisite Knowledge

The students who attend this course should have attended/should be attending the Information Retrieval course. The course will have mini-projects in Java, so familiarity with programming is desirable.

Teaching Methods

Lectures + Project

49 2.35 Advanced Topics in Data Mining I

Lecturer	Prof. Dr. Ntoutsi, Eirini (Hannover)
Weekly Composition	1
ECTS	5
Working Hours (presence/self-study)	90
Exam ID	2007
Exam Type	Written Report and Oral Presentation
Exam Duration	30 minutes
Semester	Winter

Description

Each semester we will focus on a specific data mining topic; this semester we will focus on top 10 algorithms for Data Mining/ Machine Learning.

Data Mining and Machine Learning methods are becoming very popular as the amount and the complexity of the data increases. In this seminar, we will focus on the most influential data mining algorithms, we will try to understand each algorithm, discuss its impact and review current and future research on the algorithm, in the era of Big Data.

Outcomes

- Reading and comprehending scientific work.
- Discussing scientific work, its pros and cons and how can be improved or extended.
- Reviewing known DM algorithms in the big data era and understanding what are their limitations and how one can overcome them
- Presenting to the group and being able to answer questions.
- Exchange ideas with your mentor

Recommended Literature

Survey:
Top 10 algorithms in Data Mining, http://www.cs.uvm.edu/~icdm/algorithms/10Algorithms-08.pdf

Depending on the algorithm that each student will select, specific literature will be provided. The student has also to search for related literature.

Recommended Prerequisite Knowledge

Data Mining I

Teaching Methods

Each student is assigned a mentor that helps the student to comprehend his/her algorithm and navigate through the related work w.r.t. the big data challenges.

50 2.36 Advanced Topics in Data Mining II

Lecturer	Prof. Dr. Ntoutsi, Eirini (Hannover)
Weekly Composition	2+1
ECTS	5
Working Hours (presence/self-study)	120
Exam ID	2008
Exam Type	Oral exam, graded
Exam Duration	30 minutes
Semester	Winter

Description

In many modern applications, data scientists face challenges which go beyond the basic data mining techniques taught in Data Mining I.

In this course we will cover advanced data mining techniques to handle large data volumes, volatile data streams and complex object descriptions. These topics (Volume, Velocity, Variety) comprise major challenges in Big Data analysis.

In particular we will cover:
- Big data challenges for data mining
- Mining over high dimensional data (feature selection, dimensionality reduction, high-dimensional clustering)
- Mining over large object cardinalities (parallel-, distributed-mining, summarization and sampling)
- Mining over data streams (stream classification, stream clustering, change detection)
- Multi-view and Multi-instance learning

Outcomes

At the end of the course, the students should be able to understand how the data mining techniques are affected by big data and how these techniques can be adapted to deal with big data peculiarities or what are the new techniques tailored to big data.

Recommended Literature

We dont have a specific course book and for the different topics we cover we will provide the corresponding literature.

J. Gamma, Knowledge Discovery from Data Streams, 2010.

Han J., Kamber M., Pei J., “Data Mining: Concepts and Techniques”, 3rd ed., Morgan Kaufmann, 2011

Lescovec J, Rajaraman A., Ulman J., “Mining of Massive Datasets”, Cambridge University Press, 2014

Recommended Prerequisite Knowledge

Basic data mining/ machine learning knowledge

Programming skills

Teaching Methods

- Lectures
- Tutorials focusing on gaining hand-on experience with the taught concepts
- Mini projects focusing on implementing data mining solutions from scratch or using existing tools.

51 3.01 Advanced Networking I

Lecturer	Prof. Dr. Wolf, Lars (Braunschweig)
Weekly Composition	3S
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3005
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentations incl. discussions (40min)
Semester	Winter

Description

This module deals with advanced aspects of computer networks. Instead of classic lecture (ex-cathedra teaching), active participation of the students is expected.

Outcomes

On completion of this module, the students have a deep understanding of recent advances and research trends in the area of computer networking.
Moreover, students will learn about literature-based scientific research and scientific presentation.

Recommended Literature

Every semester new research literature will be used as material. For example, in WS2011/2012, papers from the MOBICOM2011 conference were used:
http://dl.acm.org/citation.cfm?id=2030613&coll=DL&dl=GUIDE

Recommended Prerequisite Knowledge

Good knowledge about computer networks is mandatory, e.g. as taught in courses like computer networks I and II. Further courses such as 3.05 "Foundations of Mobile Communicationsäre recommended.

Teaching Methods

slide presentation, individual homework,
discussion groups,

52 3.02 Multimedia Networking

Lecturer	Prof. Dr. Wolf, Lars (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3065
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Winter

Description

This module gives a broad introduction to the design of multimedia systems and explains basic methods. The module covers requirements of multimedia systems, compression methods, protocols. Afterwards, implementation issues of multimedia systems and synchronization aspects are discussed.

Outcomes

On completion of this module, the students know the design of multimedia systems and their fundamental methods. Furthermore, they know specific problems of transmission and processing of time-critical media data over a network, as well as approaches of solving these problems.

Recommended Literature

R. Steinmetz: Multimedia Technologie. Springer-Verlag
S. Keshav: Computer Networking, Addision Wesley.

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

53 3.03 Advanced Networking II

Lecturer	Prof. Dr. Wolf, Lars (Braunschweig)
Weekly Composition	3S
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3010
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation incl. discussions (40min)
Semester	Summer

Description

This module continues and extends Advanced Networking I, but can also be taken independently of Advanced Networking I.

This module deals with advanced aspects of computer networks. Instead of classic lecture (ex-cathedra teaching), active participation of the students is expected.

Outcomes

On completion of this module, the students have a deep understanding of recent advances and research trends in the area of computer networking.
Moreover, students will learn about literature-based scientific research and scientific presentation.

Recommended Literature

Every semester new research literature will be used as material. For example, in SS2011, papers from the WONS2011 conference series were used.

Recommended Prerequisite Knowledge

Good knowledge about computer networks is mandatory, e.g. as taught in courses like computer networks I and II. Further courses such as 3.05 "Foundations of Mobile Communicationsäre recommended as well.
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Teaching Methods

slide presentation, individual homework, discussion groups

54 3.05 Foundations of Mobile Communications

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3060
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Every Semester

Description

The module gives a broad introduction to mobile wireless networks, with particular emphasis on the principles and practices used in the design of modern wireless communication systems. The module covers an introduction to wireless networks and mobility support. Afterwards, the technical basics of wireless networks are discussed, starting with an exploration of radio wave propagation and antenna design. This leads on to the study of various modern modulation methods and multiplex techniques. The theoretical basis is illustrated by recent wireless systems, such as GSM, GPRS, EDGE, HSCSD, UMTS, WLAN, WiMAX, Bluetooth, that are used in real-life. Additionally, the aspects of wireless security issues and mechanisms are discussed.

Outcomes

On completion of this module, the student will be able to
• understand the principles used in the design of mobile wireless networks
• explain the likely degradations arising from radio-wave propagation and compare the methods available to overcome them
• discuss the different modulation and multiple access methods and be aware of their strengths and weaknesses
• describe the main features of modern mobile wireless networks and recognise the trade offs which have been made in their design decisions
• be aware of the security issues and the counter measures of wireless networks
• recognise and understand the future trends in networking
• understand the follow through paths of migration from fixed networks towards mixed fixed/mobile networks.

Recommended Literature

Because this is a rapidly changing field, some of the newer literature will be announced during the lectures.

Recommended Prerequisite Knowledge

Computer Networking basics.

Teaching Methods

Lecture (recording), discussion sessions, exercise session.

55 3.06 Advanced Topics in Computer Networking I

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	3055
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (45-90 min)
Semester	periodically, according to student demand and staff specialisms

Description

This seminar focuses on current topics in the research area of computer networking. The seminar covers topics on wired and wireless IP networks including applications such as Voice over IP (VoIP), Peer-to-Peer (P2P) networks etc.

Outcomes

On completion of this module, the students have a deep understanding of recent advances and research trends in the area of computer networking.

After completing the seminar each student is able to conduct research on a small current research topic in computer networking, write a report about it and give a scientific talk on the topic to transfer the gained knowledge to their fellow students.

Recommended Literature

- A. Tanenbaum: Computer Networks, Dorling Kindersley Pvt Ltd, 2008
- C. M. Cordeiro and D. P. Agrawal: Ad Hoc and Sensor Networks: Theory and Applications, World Scientific Publishing Company, 2011
- Y.-K. R. Kwok: Peer-to-Peer Computing: Applications, Architecture, Protocols, and Challenges, CRC Press, 2011

Because this is a rapidly changing field, papers of current researches from the area of computer networking will be discussed.

Recommended Prerequisite Knowledge

none

Teaching Methods

presentation, discussion

56 3.07 Advanced Topics in Network Security

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	3015
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (30-40 min)
Semester	periodically, according to student demand and staff specialisms

Description

This seminar deals with advanced aspects of network security. It covers security aspects in common wired, but also wireless networks, such as Wireless LAN (WLAN), Wireless Sensor Networks (WSNs) and Mobile Ad Hoc Networks (MANETs). Security issues in this sort of networks are discussed, possible risks are explained and solutions are presented that can mitigate those risks.

Outcomes

On completion of this module, the students have a deep understanding of recent advances and research trends in the area of network security.

After completing the seminar each student is able to conduct research on a small current research topic in network security, write a report about it and give a scientific talk on the topic to transfer the gained knowledge to their fellow students.

Recommended Literature

- C. Douligeris, D. N. Serpanos: Network Security: Current Status and Future Directions, Wiley-IEEE Press, 2007
- C. M. Cordeiro and D. P. Agrawal: Ad Hoc and Sensor Networks: Theory and Applications, World Scientific Publishing Company, 2011
- E. Cayirci and C. Rong: Security in Wireless Ad Hoc and Sensor Networks, Wiley, 2009

Because this is a rapidly changing field, papers of current researches from the area of computer networking will be discussed.

Recommended Prerequisite Knowledge

none

Teaching Methods

presentation, discussion

57 3.08 Advanced Topics in Mobile Communications III

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2L + 1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3048
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

This module focuses on advanced topics in the area of mobile communication. The module covers topics, such as, Wireless Wide Area Networks (WWAN), Wireless LAN (WLAN), Wireless Sensor Networks (WSNs) and Mobile Ad Hoc Networks (MANETs). Security issues in this sort of networks are discussed, possible risks are explained and solutions are presented that can mitigate those risks.

Outcomes

On completion of this module, the students have a deep understanding advanced topics in the area of mobile communication.
After completing the module each student is able to conduct research on a small current research topic in mobile communication.

Recommended Literature

Because this is a rapidly changing field, up to date literature topics from the area of mobile communication will be discussed.

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

58 3.09 Advanced Topics in Internet Research (I)

Lecturer	Prof. Dr. Fu, Xiaoming (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3030
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (45-90 min)
Semester	periodically, according to student demand and staff specialisms

Description

This module focuses on reading, presenting and reproducing researches related to networking including wired / wireless networking and/or mobile computing. There are no exams, but reports and presentations/demos are required, and the participation will be evaluated. The module includes the following themes: experimental networking research: concepts, tools, and research methodologies. The material in the module are drawn mainly from the research literature.

Outcomes

On completion of this course, besides having obtained a deep understanding on recent advances in internet research and networking, the students are able to:
- read articles/papers published in the field of Internet research and networking from a scientific perspective
- present their findings in scientific fashion based on the learned concepts and tools
- find interesting research problems within recent literature

Recommended Literature

Session-specific literature will be announced during the course.
Additional readings:
Michael J. Hanson, Efficient reading of papers in science and technology, Brochure, 1989.
Mark Handley, Why the Internet only just works?, BT Technology Journal, 24(3): 119-129, July 2006.

Recommended Prerequisite Knowledge

Basic knowledge in computer networks

Teaching Methods

Presentation, discussion

59 3.10 Advanced Topics in Internet Research (II)

Lecturer	Prof. Dr. Fu, Xiaoming (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3050
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (45-90 min)
Semester	periodically, according to student demand and staff specialisms

Description

This module deals with advanced aspects of Internet research including wired, wireless networking and/or mobile computing. Those aspects include Peer-to-Peer (P2P) networking, cloud computing, etc.

Outcomes

On completion of this module, the students have a deep understanding of recent advances and research trends in the area of Internet research and mobile computing.

Each student is able to write a report and give a scientific talk on the topic to transfer the gained knowledge to their fellow students.

Recommended Literature

Because this is a rapidly changing field, some of the newer literature will be announced during the course. Besides, the following literature is recommended:

- A. Tanenbaum: Computer Networks, Dorling Kindersley
Pvt Ltd, 2008
- C. M. Cordeiro and D. P. Agrawal: Ad Hoc and Sensor
Networks: Theory and Applications, World Scientific
Publishing Company, 2011
- Y.-K. R. Kwok: Peer-to-Peer Computing: Applications,
Architecture, Protocols, and Challenges, CRC Press, 201

Recommended Prerequisite Knowledge

Basic knowledge in computer networks

Teaching Methods

Presentation, discussion

60 3.11 Advanced Topics in Mobile Communications II

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	3046
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (45-90 min)
Semester	periodically, according to student demand and staff specialisms

Description

This seminar focuses on current topics in the research area of computer networking. The seminar covers topics on wired and wireless IP networks including applications such as Voice over IP (VoIP), Peer-to-Peer (P2P) networks etc.

Outcomes

On completion of this module, the students have a deep understanding of recent advances and research trends in the area of computer networking.

After completing the seminar each student is able to conduct research on a small current research topic in computer networking, write a report about it and give a scientific talk on the topic to transfer the gained knowledge to their fellow students.

Recommended Literature

- A. Tanenbaum: Computer Networks, Dorling Kindersley Pvt Ltd, 2008
- C. M. Cordeiro and D. P. Agrawal: Ad Hoc and Sensor Networks: Theory and Applications, World Scientific Publishing Company, 2011
- Y.-K. R. Kwok: Peer-to-Peer Computing: Applications, Architecture, Protocols, and Challenges, CRC Press, 2011

Because this is a rapidly changing field, papers of current researches from the area of computer networking will be discussed.

Recommended Prerequisite Knowledge

none

Teaching Methods

presentation, discussion

61 3.12 Introduction to Computer Security

Lecturer	Prof. Dr. Rieck, Konrad (Göttingen)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3040
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

This course deals with principles of computer and network security. The course covers basic concepts of security and introduces common attacks and defenses. Topics of the course include basic cryptography, authentication and authorization, vulnerabilities and attacks, malicious software, and privacy aspects.

Outcomes

After successful completion of the modul students are able to
- Describe and apply symmetric-key cryptosystems
- Describe and apply public-key cryptosystems
- Apply and compare mechanisms for authentication and access control
- Explain attacks on different networks layers
- Apply and compare defenses against network attacks
- Identify vulnerabilities in software and use countermeasures
- Describe types and mechanisms of malware
- Apply and compare methods for intrusion and malware detection
- Describe and use honeypot and sandbox systems

Recommended Literature

M. Bishop: Computer Security - Art and Science. Macmillian Publishing, 2002
D. Gollmann: Computer Security. Wiley & Sons, 2011
B. Schneier: Applied Cryptography. Wiley & Sons, 1995
P. Szor: The Art of Computer Virus Research and Defense. Addison-Wesley, 2005

Recommended Prerequisite Knowledge

none

Teaching Methods

slide presentation; practical exercises

62 3.13 Advanced Topics in Mobile Communications I

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2L + 1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3045
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Winter

Description

This module deals with advanced aspects of mobile communication with a special focus on newer research areas such as Wireless Sensor Networks (WSNs) and Mobile Ad Hoc Networks (MANETs). New approaches and challenges are presented to deal with the contraints and requirements of mobile communication networks.

Outcomes

On completion of this module, the students have a deep understanding of recent advances and research trends in the area of mobile communication.

The students are able to identify and recognise typical wireless communication problems and to provide solutions or approaches to overcome these problems.

Recommended Literature

* C. Murthy, B. Manoj: Ad Hoc Wireless Networks: Architectures and Protocols, Prentice Hall, 2004
* R. Bless: Protocols and Architectures for Wireless Sensor Networks, Springer, 2005
* S. Kumar Sarkar, T G Basavaraju, C Puttamadappa: Ad Hoc Mobile Wireless Networks: Principles, Protocols, and Applications, Auerbach Publications, 2007
* Azzedine Boukerche, et. al.: Algorithms and Protocols for Wireless Sensor Networks, Wiley Series on Parallel and Distributed Computing, 2008
* Raja Jurdak, Cristina Videira Lopes and Pierre Baldi: A Survey, Classification, and Comparative Analysis of Medium Access Control Protocols for Ad Hoc Networks, IEEE Communications Surveys and Tutorials 6:1, 2004
* Audun Jøsanga, Roslan Ismailb and Colin Boydb: A survey of trust and reputation systems for online service provision, Emerging Issues in Collaborative Commerce, 2007
* Ahmad Al Hanbali, Eitan Altman and Philippe Nain: A survey of TCP over Ad hoc Networks, IEEE Communications Surveys and Tutorials, 2005

=> Because this is a rapidly changing field, some of the newer literature will be announced during the lectures.

Recommended Prerequisite Knowledge

Foundations of Mobile Communications

Teaching Methods

Slide presentation, exercises, discussions

63 3.14 Practical Course on Advanced Networking

Lecturer	Prof. Dr. Fu, Xiaoming (Göttingen)
Weekly Composition	4P
ECTS	6
Working Hours (presence/self-study)	56/94
Exam ID	3020
Exam Type	Oral exam, graded
Exam Duration	written report (12-14 pages) + presentation incl. discussion (40min)
Semester	Summer and Winter

Description

This module provides a couple of practical topics related to advanced computer networking. The students will conduct the practical course in small teams. A team consist of 2 students.

Outcomes

On completion of this module students will have:
* Learned to architect, develop, and test a network application or protocol.
* Learned to work effectively in a team environment and project-style development.
* Developed their written and oral communication skills in English.
* Become proficient with software development tools and networking environments, using standard programming language C/C++/Java/... and tools (such as CVS, Eclipse).

Recommended Literature

Not bounded to a textbook, as the topic maybe adjusted according to the latest technology trend.
Some general readings could be useful, e.g., 1. W. Richard Stevens, Advanced Programming in the UNIX Environment, Addison-Wesley.

Recommended Prerequisite Knowledge

Basis knowledge in computer networks

Teaching Methods

Practical exercises, group work, presentation

64 3.15 Peer-to-Peer Networks

Lecturer	Prof. Dr. Nejdl, Wolfgang (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3035
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Winter

Description

This module gives an introduction into the peer-to-peer paradigm and provides an overview of techniques used in P2P networks. Focus of this lecture is the presentation of different topologies and routing strategies. In addition, various applications on top of the topology level are treated, such as information retrieval and streaming.

Outcomes

On completion of this module, the students are familiar with the fundamentals of self-organizing networks, have an understanding of common peer-to-peer topologies and algorithms, and know the advantages and disadvantages of peer-to-peer technology for various applications.

Recommended Literature

Ralf Steinmetz, Klaus Wehrle: Peer-to-Peer Systems and Applications, Springer.

Recommended Prerequisite Knowledge

none

Teaching Methods

slide presentation, homework, exercise groups

65 3.16 Selected Topics in Internet Technologies

Lecturer	Prof. Dr. Fu, Xiaoming (Göttingen)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3052
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (45-90 min)
Semester	periodically, according to student demand and staff specialisms

Description

The seminar module covers selected topics from current research and technology approaches in computer networking, with a technological orientation. Example topics cover advances in cloud computing, peer-to-peer (P2P) networks, social networks, etc.

Outcomes

On completion of this course, besides having obtained a deep understanding on recent advances in internet research and networking, the students are able to:
- read articles/papers published in the field of Internet research and networking from a scientific perspective
- present their findings in scientific fashion based on the learned concepts and tools
- write a detailed report about one selected topic
- find relevant research problems within the discussed literature

Recommended Literature

Topic-specific literature will be announced during the course.
General literature:
Michael J. Hanson: Efficient reading of papers in science and technology, Brochure, 1989.
Ashwin Ram, GaTech: How to Present a Paper.
Henning Schulzrinne, Columbia U.: Writing Technical Articles in computer science and electrical engineering, with emphasis on papers in systems and networks.
William J. Rapaport, SUNY Buffalo: How to Study

Recommended Prerequisite Knowledge

Basic knowledge in computer networks

Teaching Methods

presentation, discussion

66 3.17 Selected Topics in Advanced Networking

Lecturer	Prof. Dr. Fu, Xiaoming (Göttingen)
Weekly Composition	2L
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3025
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

The module covers selected topics from advanced networking, with an objective of forming fundamental basis for emerging network technologies and new research. The module is implemented on a series of lectures with small-scale course projects, which cover the fields of Peer-to-Peer (P2P), Social networks and mathematical modeling for advanced networking purposes among others.

Outcomes

On completion of this module, the students have obtained a deep, detailed insight into several specific topics, which are fundamental for a further development of research and computer networking skills. The students will have a specialized knowledge of both theoretical (e.g. mathematical modeling) and practical (e.g. social networking) nature.

Recommended Literature

Topic-specific literature will be announced during the course. Fundamental literature includes:

- A. Tanenbaum: Computer Networks, Dorling Kindersley Pvt Ltd, 2008
- C. M. Cordeiro and D. P. Agrawal: Ad Hoc and Sensor Networks: Theory and Applications, World Scientific Publishing Company, 2011
- Y.-K. R. Kwok: Peer-to-Peer Computing: Applications, Architecture, Protocols, and Challenges, CRC Press, 201

Recommended Prerequisite Knowledge

Basic knowledge in computer networks

Teaching Methods

Slide presentation, exercises, discussions

67 3.18 Practical Course in Advanced Topics in Mobile Communication

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2P
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3047
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

In this practical course hands-on lab exercises in advanced areas of mobile communications will be offered to deepen the theoretical background and to apply the gained knowledge real-life scenarios. For example, current simulation tools from the area of mobile communications are introduced and experiments are conducted to test different mobile scenarios. Furthermore, a test-bed is provided that allows students to experiment with real hardware devices, such as wireless sensor nodes, in small groups.

Outcomes

On completion of this module, the students have learned how to apply their theoretical foundations from the area of mobile communication to real-life applications. On the basis of independently conducted practical experiments the students are able to assess the requirements of real-life applications, the involved risks and how to mitigate those risks. Furthermore, the students have been made aware of the challenges that can arise in the area of wireless devices and how to deal with those challenges. The lab enables the students to accomplish a full development cycle from the idea, to the design, to the implementation and testing of a real-life application.

Recommended Literature

- Philip Levis and David Gay: TinyOS Programming, Cambridge University Press, 2009
- R. Bless: Protocols and Architectures for Wireless Sensor Networks, Springer, 2005
- Waltenegus Dargie, Christian Poellabauer: Fundamentals of Wireless Sensor Networks: Theory and Practice, John Wiley & Sons, 2010
- Evon M. O. Abu-Taieh und Asim Abdel Rahman El Sheikh: Handbook of Research on Discrete Event Simulation Environments: Technologies and Applications, Idea Group Reference, 2009

Recommended Prerequisite Knowledge

Advanced Topics in Mobile Communication

Teaching Methods

practical exercises, group work, presentation

68 3.19 Advanced Topics in Network Security II

Lecturer	Prof. Dr. Hogrefe, Dieter (Göttingen)
Weekly Composition	2L + 1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	3016
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

This course reviews major security and privacy issues in wireless networks with a focus on ad hoc and sensor networks. Security of the existing wireless networks, secure routing, selfish node behaviours, malicious node behaviours as well as privacy preserving mechanisms are among the topics. In selfish behaviour topic, the concept of cooperation is formalised using game theory as a tool. An introduction to cryptography is provided at the begining of the lecture, but some prior knowledge of cryptography would be helpful.

Outcomes

After successfully completing this course the students will be able to understand principal concepts of wireless networks and how to secure them. The students will be aware of the vulnerabilities of wireless, self-organized networks as well as the building blocks of the most important existing solutions, such as security and privacy challenges. On completion of this course the students will be able to describe the concepts of trust management, cooperation, secure neighbour discovery and privacy protection as well as selfishness and misbehavioring in wireless networks.

Recommended Literature

L. Buttyan and J.-P. Hubaux: Security and cooperation in wireless networks, Cambridge University Press, 2007

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, video recordings, exercises, discussions

69 3.20 Digital Systems

Lecturer	apl. Prof. Dr. Kemnitz, Günter (Clausthal)
Weekly Composition	2L+2L
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	3066
Exam Type	Written or oral exam, graded
Exam Duration	Written report and oral presentation (30-45min)
Semester	Summer

Description

The course starts with the design of digital circuits using VHDL: simulation, synthesis, programming into Xilinx-FPGAs, and testing. The difficuilty of the classes increases from combinatorial circuits of a few gates up to simple graphic adapter functions. In the second part of the course, processor systems will be assemled out of predesigned soft cores: processors, memory controllers etc. Programming language will be C.

Outcomes

On successful completion of this module students are able to analyse, design, simulate and test complex digital systems (digital circuits and processor systems) and have acquired practical experience with the digital systems design process.

Recommended Literature

- Ashenden: The Designer's Guide to VHDL, Morgan Kaufmann, 2008

Recommended Prerequisite Knowledge

The module presumes programming skills in C and a prior understanding of digital systems as, for example, acquired through an introductory module on computer engineering at undergraduate level.

Teaching Methods

Individual projects, lab work, homework, in-class presentations, group discussions

70 3.21 Computer Security and Machine Learning

Lecturer	Prof. Dr. Rieck, Konrad (Göttingen)
Weekly Composition	2L+2E
ECTS	6
Working Hours (presence/self-study)	56 / 94
Exam ID	3067
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

The course deals with the combination of machine learning and computer security. Approaches for automatically detecting and analyzing security threats in the Internet are presented. Topics include network anomaly detection, automatic signature generation, classification and clustering of malicious software.

Outcomes

After successful completion of the modul students are able to
- Differentiate different types of learning methods
- Analyse and design feature spaces for security problems
- Create kernel functions for security problems
- Explain learning methods for classification and anomaly detection
- Apply and compare learning methods for network intrusion detection
- Explain learning methods for clustering
- Apply and compare learning methods for malware analysis
- Describe signature generation and evasion attacks
- Explain learning methods for dimension reduction
- Apply and compare learning methods for vulnerability discovery

Recommended Literature

J. Shawe-Taylor and N. Cristianini. Kernel Methods for Pattern Analysis. Cambridge 2004.
T. Mitchell. Machine Learning. McGraw-Hill, 1997
D. Gollmann: Computer Security. Wiley & Sons, 2011
P. Szor: The Art of Computer Virus Research and Defense. Addison-Wesley, 2005

Recommended Prerequisite Knowledge

none

Teaching Methods

slide presentation; practical exercises

71 3.22 Advanced Topics in Embedded Systems Engineering

Lecturer	Prof. Dr. Siemers, Christian (Clausthal)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	42 / 83
Exam ID	3068
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25 min)
Semester	periodically, according to student demand and staff specialisms

Description

The course gives an introduction into methodologies for the design and development of complex digital systems, programmable systems, real-time systems, and operating systems as virtual machines.
The course also covers common test procedures for embedded systems, and discusses case studies on current distributed embedded applications.

Outcomes

On successful completion of this module students are able to design, implement and test software of embedded systems, to consider and assess relevant resource restrictions, and to use design patterns for building applications.

Recommended Literature

- Catsoulis: Designing Embedded Hardware, O'Reilly
- Marwedel: Embedded System Design, Springer
- Schmitt, von Wendorff, Falk, Marwedel: Source Code Optimization Techniques for Data Flow Dominated Embedded Software, Kluwer
- Scholz: Softwareentwicklung eingebetteter Systeme, Springer
- Vahid, Givargis: Embedded Systems Design, Wiley
- White: Making Embedded Systems: Design Patterns for Great Software, O'Reilly
- Westerholz: Embedded Control Architekturen, Hanser

Recommended Prerequisite Knowledge

The module presumes a prior understanding of embedded systems as, for example, acquired through an introductory module on embedded systems at undergraduate level.

Teaching Methods

Beamer presentation, whiteboard, homework

72 3.23 Internet of Things

Lecturer	Prof. Dr. Siemers, Christian (Clausthal)
Weekly Composition	2S
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	3069
Exam Type	Written Report and Oral Presentation
Exam Duration	Presentation (30-45min)
Semester	periodically, according to student demand and staff specialisms

Description

This seminar is dedicated to the discussion of trends and recent advances relevant for the Internet of Things. You are provided exposure to topics beyond the standard curriculum.

In the beginning of the semester, instruction is given in how to review research literature, devise research talks and essays, find relavant background literature, and practise presentation skills.

For the seminar you will read a research paper, prepare an oral presentation emphasising the research goals, methods, and solutions proposed in the paper, and deliver the presentation in class. For your presentation you will receive feedback from the lecturer and your peers. Taking into account the feedback you will then write a essay reviewing the chosen paper and elaborating the subject by gathering more background information. You will also attend the presentations by your peers, and participate actively in class discussions that accompany their presentations.

Outcomes

On successful completion of the module, you will be able to read and analyse research literature, identify research questions and strategies used for their settlement, review research contributions, communicate effectively through technical presentations and written essays, critique presentations, and engage in research-oriented discussions.

Recommended Literature

Varies every semester depending on topic. As the seminar has its focus on current directions in research, the recommended literature will mainly consist of recent articles from topic-specific international conferences or journals.

Recommended Prerequisite Knowledge

The module presumes a prior understanding of digital, embedded or information systems as, for example, acquired through an introductory module on these subjects at undergraduate level.

Teaching Methods

Student presentations, group discussions

73 3.24 Recent Topics in Computer Networking

Lecturer	Prof. Dr. Wolf, Lars (Braunschweig)
Weekly Composition	2L+1E (partially blocked)
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3070
Exam Type	Oral exam, graded
Exam Duration	25 min
Semester	Winter

Description

In this course we look at recent developments and research trends in the field of computer networking. We will talk primarily about Wireless Sensor Networks and Delay Tolerant Networks.

Outcomes

On completion of this module, the students have obtained a deep, detailed insight into several specific topics, which are fundamental for a further development of research and computer networking skills especially in the recent fields of WSNs and DTNs.

Recommended Literature

Topic-specific literature will be announced during the course.

Recommended Prerequisite Knowledge

Good understanding of computer networks in general and mobile&wireless communication in particular is mandatory, e.g. as taught in courses like computer networks I and II (at TUBS) and further courses such as 3.05 "Foundations of Mobile Communications".

Teaching Methods

Slide presentation, exercises/assignments, discussions

74 3.25 Networking and Multimedia Lab

Lecturer	Prof. Dr. Wolf, Lars (Braunschweig)
Weekly Composition	2P
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3071
Exam Type	Written Report and Oral Presentation
Exam Duration	25 min
Semester	Summer and Winter

Description

In this practical course hands-on lab exercises in advanced areas of mobile communications will be offered. Additionally, students have to design, implement, test, evaluate, and finally demonstrate some applications for real-world needs.

Outcomes

On completion of this module, the students have learned how to apply their theoretical foundations from the area of multimedia systems, computer networking and mobile communication to real-life applications. Typical tasks for the students are to design, implement, evaluated, and demonstrate some small applications, e.g., Apps for Android devices.

Therefore, students are able to assess the requirements of real-life applications, the involved risks and how to mitigate those risks.
The lab enables the students to accomplish a full development cycle from the idea, to the design, to the implementation and testing of a real-life application.

Recommended Literature

Not bounded to a specific textbook, as the topic maybe adjusted according to the latest technology trend. Some general readings which could be useful are books on computer networking and mobile communication, e.g.:
- Andrew S. Tanenbaum: Computer Networks, Pearson Education International
- James F. Kurose, Keith W. Ross: computer networking, A Top-Down Approach Featuring the Internet, Addison Wesley
- J. Schiller: Mobile Communications, Addison-Wesley

Recommended Prerequisite Knowledge

Good understanding of computer networks in general and mobile&wireless communication in particular is expected, e.g. as taught in courses like computer networks I and II (at TUBS) and further courses such as 3.05 "Foundations of Mobile Communications".

Teaching Methods

practical exercises, group work, presentation

75 3.26 Wireles Sensor Networks Lab

Lecturer	Prof. Dr. Wolf, Lars (Braunschweig)
Weekly Composition	2P
ECTS	5
Working Hours (presence/self-study)	28/97
Exam ID	3072
Exam Type	Written Report and Oral Presentation
Exam Duration	25 min
Semester	Summer and Winter

Description

In this practical course, students get hands-on access and experiences with wireless sensor networks hard- and software. They will design, implement, test, evaluate, and finally demonstrate some WSN applications, potentially including own HW extensions.

Outcomes

On completion of this module, the students have good insight into the field of WSNs. This includes WSN internal mechanisms as well as application scenarios.
Therefore, they learned how to apply their theoretical foundations to real-life applications and are able to assess the requirements of real-life applications, the involved risks and how to mitigate those risks.
The lab enables the students to accomplish a full development cycle from the idea, to the design, to the implementation and testing of a real-life application.

Recommended Literature

Not bounded to a specific textbook, as the topic maybe adjusted according to the latest technology trend. Some general readings which could be useful are books on computer networking and mobile communication as ell as WSN related books, e.g.:
- Andrew S. Tanenbaum: Computer Networks, Pearson Education International
- James F. Kurose, Keith W. Ross: computer networking, A Top-Down Approach Featuring the Internet, Addison Wesley
- J. Schiller: Mobile Communications, Addison-Wesley
- Holger Karl, Andreas Willig: Protocols and Architectures for Wireless Sensor Networks, Wiley

Recommended Prerequisite Knowledge

Good understanding of computer networks in general and mobile&wireless communication in particular is expected, e.g. as taught in courses like computer networks I and II (at TUBS) and further courses such as 3.05 "Foundations of Mobile Communications".
Also, Module 3.24 "Recent Topics in Computer Networkingïs highly recommended.

Teaching Methods

practical exercises, group work, presentation

76 3.27 Future Internet Communication Technologies

Lecturer	Jun.-Prof. Dr. Papadimitriou, Panagiotis (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42
Exam ID	3075
Exam Type	Written exam, graded
Exam Duration	90 min
Semester	Summer

Description

The course aims to provide a theoretical and practical understanding of the technologies that are going to shape the next-generation Internet, such as software routers, network and router virtualization, and software-defined networks.

Outcomes

Students will become familiar with technologies and future trends in terms of packet switching„ flow processing (programmable switches, OpenFlow), congestion control (congestion control for large bandwidth-delay products, delay-based congestion control, multi-path TCP), overlay networks, content distribution networks, and network virtualization (router virtualization, network interface virtualization).

Recommended Literature

Lecture slides and a list of research papers and surveys. The textbook by J. F. Kurose and K. W. Ross “Computer Networking: A Top-Down Approach” is recommended as source material for state-of-the-art Internet protocols and technologies.

Recommended Prerequisite Knowledge

Good understanding of Internet architecture and protocols (e.g., TCP/IP).

Teaching Methods

Lectures include the presentation of Internet communication technologies and discussion with students. Exercises and lab sessions allow the students to obtain practical experience with various technologies.

77 3.28 Network Management

Lecturer	Jun.-Prof. Dr. Papadimitriou, Panagiotis (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42
Exam ID	3080
Exam Type	Oral exam, graded
Exam Duration	30 min
Semester	Winter

Description

This course aims to provide a theoretical and practical understanding of principles, technologies and architectures for the management of IP networks, including transit, enterprise and data-center networks as well as virtualized network infrastructures.

Outcomes

Students will become familiar with principles and technologies for network management (SNMP) and the configuration of end-hosts (network discovery and bootstrapping with DHCP, ARP), routers (implementation of routing policies with BGP) and middleboxes (NATs, firewalls, application gateways, intrusion detection systems). Students will be able to understand how virtualized networks should be managed in order to provide elasticity, fault tolerance and/or energy efficiency. Furthermore, students will learn about recent architectures and trends that simplify network management and minimize the configuration overhead in large enterprise and data-center networks.

Recommended Literature

Lecture slides, research papers and state-of-the-art surveys.

Recommended Prerequisite Knowledge

Good understanding of Internet architecture and protocols (e.g., TCP/IP).

Teaching Methods

Lectures include the presentation of network management principles and technologies, and discussion with students. Exercises and lab sessions allow the students to obtain practical experience with various aspects and techniques for network management.

78 3.29 Teletraffic Theory

Lecturer	Prof. Dr.-Ing. Fidler, Markus (Hannover)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42
Exam ID	3085
Exam Type	Written exam, graded
Exam Duration	90
Semester	Winter

Description

This module covers analytical methods for performance evaluation of communication networks. The course first provides an introduction to teletraffic theory and quality of service architectures. This leads to the study of deterministic methods for worst-case analysis of networks using the so-called network calculus. Then, after an introduction to probability theory and Markov chains, stochastic methods such as classical queueing theory and effective bandwidths will be discussed.

Outcomes

Students will become familiar with principles and methods for network performance evaluation. On completion of this module, students will be able to understand
- how quantitative quality of service guarantees can be provided
- how communication systems and networks are dimensioned
- how statistical multiplexing achieves major resource savings
- how parameters of the data traffic impact network performance

Recommended Literature

Lecture slides, research papers and state-of-the-art surveys.

Recommended Prerequisite Knowledge

Computer Networking, Communications Protocols

Teaching Methods

Lectures and Exercises

79 3.30 Hardware Software Co-Design

Lecturer	Prof. Dr. Siemers, Christian (Clausthal)
Weekly Composition	3L+1S
ECTS	6
Working Hours (presence/self-study)	75/50
Exam ID	
Exam Type	Written Report and Oral Presentation
Exam Duration	30min
Semester	Winter

Description

This course investigates the concurrent design of hardware and software components of complex electronic systems to exploit the synergy of hardware and software with the goal to optimize and/or satisfy design constraints such as cost, design efficiency, level of abstraction, performance, power consumption, responsibility, reconfigurability, scalability, technology, to name a few. Moreover, the hardware/software co-design approach targets to reduce the time-to-market frame of products considerably.

Winter Class Hardware-Software Co-Design is divided into two parts: Part I: Structural Concept of HSCD, Architectures of HSCD, Design Methods, Hardware Description Languages, Models for Design Representation, Generalized Attempts for HSCD, Partitioning Based on Data- and Control Flow Graphs, Algorithms for Hardware/Software Partitioning, Estimating the Design Quality, HSCD Use Cases to integrate the essential knowledge for own HSCDclass work. Part II.: HSCD Seminar / Project work in a student chosen area of concentration from Part I.

Outcomes

The scope of module hardware/software co-design (HSCD) is to conciliate a well defined and well chosen theoretical and methodological background on methods and tools for hardware/software co- design, starting with a historical survey with regard to the structural concept of HSCD, highlighting its major architectures, design methods, models for design representation, partitioning based on specialized algorithms and methods such as data and control flow graphs, design of embedded HSCD systems, and finally introducing use cases such as reconfigurable and scalable computing including field programmable gate arrays (FPGA) and nano-electronic devices such as spin valves with the objective including HSCD. Background to earn these competencies is not only based on the primary computer science knowledge, which is understood as knowledge for the sake of action out of the synthesis of mathematical methodology and engineering concreteness, realized in the technical HSCD based construct, but also a strategic knowledge of orientation which allow the self-contained handling of knowledge within complex project situations, e.g. to constitute the use of the right HSCD composition for a concrete application domain.

Recommended Literature

tbc

Recommended Prerequisite Knowledge

Teaching Methods

tbc

80 3.31 Introduction to Software-defined Networking

Lecturer	Prof. Dr. Fu, Xiaoming (Göttingen)
Weekly Composition	Block course
ECTS	5
Working Hours (presence/self-study)	60/60
Exam ID	3079
Exam Type	Written Report and Oral Presentation
Exam Duration	20-30 minutes
Semester	Winter (biyearly)

Description

Software-defined networking (SDN) has recently attracted both researchers and engineers in academia and big players in communication technologies. In this course, we will discuss the basics of SDN. The course is organized as a block course that introduces the main motivation, concepts and state-of-the-art of SDN. Students will be taught in lecture and seminar sessions as well as practical exercises.

Outcomes

Goals:
The students
- are familiar with the concepts of software defined networking (SDN)
- know how to methodically read and analyse scientific research papers
- have enriched their practical skills in computer networks with regards to SDN - know about practical deployability issues of SDN - have improved their ability to work independently in a pre-defined context

Recommended Literature

Software Defined Networking (SDN)

Recommended Prerequisite Knowledge

Basic networking and programming skills

Teaching Methods

Lectures, exercises, Paper reading in groups and group discussions

81 3.32 Specialization Software-defined Networking

Lecturer	Prof. Dr. Fu, Xiaoming (Göttingen)
Weekly Composition	Block course
ECTS	5
Working Hours (presence/self-study)	60/60
Exam ID	3082
Exam Type	Written Report and Oral Presentation
Exam Duration	20-30 minutes + report
Semester	Winter (biyearly)

Description

Software-defined networking (SDN) has recently attracted both researchers and engineers in academia and big players in communication technologies. In this course, we will discuss advanced concepts of SDN. The course is organized as a block course that, building on the basics of SDN, investigates the most recent advances of SDN in both academia and industry. Students will be taught in lecture and seminar sessions as well as practical exercises.

Outcomes

Goals:
The students
- are familiar with advanced concepts of software defined networking (SDN)
- know how to methodically read, analyse and discuss scientific research papers
- have enriched their practical skills in computer networks with regards to SDN and its applications
- know about practical deployability issues of SDN
- have improved their ability to work independently in a pre-defined context
- have improved their ability to work in diverse teams

Recommended Literature

Software Defined Networking (SDN)

Recommended Prerequisite Knowledge

Basic networking and programming skills

Teaching Methods

Lectures, Exercises, Paper reading in groups and group discussions

82 3.33 Advanced Topics in Machine Learning

Lecturer	Prof. Dr. Rieck, Konrad (Göttingen)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	36 / 89
Exam ID	3083
Exam Type	Written Report and Oral Presentation
Exam Duration	1
Semester	periodically, according to student demand and staff specialisms

Description

The course will focus on Machine learning and activity recognition from sensor-data.

Course topics
- Introduction to Machine learning
- Supervised and Unsupervised learning
- Features and feature extraction
- Feature subset selection
- Performance metrics
- Model selection
- Polynomial curve fitting
- Support Vector Machines
- Artificial Neural Networks
- k-NN
- SOM
- Decision trees
- Naive Bayes and Bayesian networks
- HMM
- Conditional Random Fields
- Topic models
- Deep learning
- Dimensionality reduction
- Anomaly detection
- Recommender systems

Outcomes

The course will address selected topics in Pervasive Computing with a special focus on Machine learning and activity recognition from sensor-data. In addition, other fields of Pervasive Computing are covered to provide students with a good overview on current advances and research challenges. Depending on the interest of the students, the emphasis on these additional topics may differ.

Recommended Literature

Bishop, Christopher M. Pattern recognition and machine learning. Vol. 1. New York: springer, 2006.

Duda, Richard O., Peter E. Hart, and David G. Stork. Pattern classification. John Wiley and Sons, 2012.

Witten, Ian H., and Eibe Frank. Data Mining: Practical machine learning tools and techniques. Morgan Kaufmann, 2005.

Recommended Prerequisite Knowledge

Teaching Methods

slides and smartboard, practical projects

83 4.01 Electronic Business and Operations Research, case study based

Lecturer	Prof. Dr. Schumann, Matthias (Göttingen)
Weekly Composition	3L+1E
ECTS	6
Working Hours (presence/self-study)	56 / 94
Exam ID	4050
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Summer

Description

The module describes the essential design of the production and the distribution in E-Business. Resource-oriented aspects for establishing the business are being explained. The effects of standardization (protocols, interfaces) in E-Business will be discussed. Electronic markets and electronic tracking systems will be presented. Furthermore, an overview of supply chains and supply chain management will be given. The module covers special features of enterprises producing and distributing digital products, additionally, specifics of TIME-markets will be presented. The following OR-methods will be elucidated:
- linear programming for production and sales planning
- diffusion models for digital products
- auction mechanisms
- the bullwhip-effect
- demand planning using statistics
- models for stock-keeping
- vehicle routing problems
- quantification of standardization effects

Three case studies will be presented:
- standardization within the supply chain
- demand planning for an online distribution system
- the ruin of the music industry .

Outcomes: On completion of the module, the student should be able to
- understand the basic formal principles and mechanisms of E-Business
- understand the functionality of electronic trading systems and establish a relation to the entire range of electronic markets
- explain the special features of digital products and TIME markets
- solve special planning problems on the basis of the methods presented
- elaborate approaches for new tasks in this field
- classify new approaches and assess existing business models.

Outcomes

On completion of the module, the student should be able to
- understand the basic formal principles and mechanisms of E-Business

• understand the functionality of electronic trading systems and establish a relation to the entire range of electronic markets
• explain the special features of digital products and TIME markets
• solve special planning problems on the basis of the methods presented
• elaborate approaches for new tasks in this field
• classify new approaches and assess existing business models.

Recommended Literature

Detailed literature will be announced during the lectures.
Basic literature:
R. Wiegand, A. Picot, R. Reichwald, Information Organization and Management, Cichester et al., 1997
A. Barua, P. Konana, A.B. Whinston, F. Yin, Driving E-Business Excellence, MIT Sloan Management Review 2001, 1, pp. 36-44
D. Chaffey, E-Business and e-Commerce Management, 3rd ed. Prentice Hall, 2007
M. Meyer, M. Wagner, J. Roder, Structure of Advanced Planning Systems, in: H. Stadtler, C. Hilger, Supply Chain Management and Advanced Planning, 2nd ed., Berlin et al., 2002, pp. 99-104
C. Subramaniam, M.Y. Shaw, The Effects of Process Characteristics on the Values of B2B E-Procurement, in: Information Technology and Management, 5(2004) 1, pp. 161-180

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

84 4.02 Multimedia and Telecommunications Law

Lecturer	Prof. Dr. Spindler, Gerald (Göttingen)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	4040
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	periodically, according to student demand and staff specialisms

Description

The module gives a broad introduction to Internet Technologies and Information Systems Law with particular emphasis on practices used in modern communication systems. The module covers an introduction to the relevant basics from German Constitutional Law with a focus on fundamental rights, namely the privacy of correspondence, posts, and telecommunications (Art. 10 GG) and the freedom of expression and information, freedom of the press (Art. 5 I GG). Further, the legal regulation of the telecommunications industry as defined by the Telecommunications Act and by changes resulting from the competence of the European Commission, e.g. Telecom Package will be discussed. Additionally, the aspects of civil liability of multimedia users, providers and developers as stipulated e.g. in the Teleservices Act, in Copyright Law and the German Civil Code are discussed including current issues like access blocking, leading on to a study of Contract Law regarding contracts between users, providers, developers etc. Furthermore, we will discuss data protection issues arising in the context of new media focusing on the rules of the Teleservices Act and the Data Protection Acts on federal (Bund) and regional (Länder) level. This includes an analysis of inter alia data-mining and cookies. Domain Law, including problems concerning domain names, domain grabbing and trademark issues will also be looked at. Another focus will be on Software Law and Open Source Software in particular, considering relevant issues from Patent Law, Copyright Law and Trademark Law. The module will also address advertising issues like spam from the viewpoint of German Unfair Competition and Consumer Protection law. Another part of the module will deal with the supervision of the media focusing on protection of minors and Access Verifying Systems as well as computer related aspects of Criminal Law. Lastly, the restrictions to online services like gaming, gambling and lotteries will be discussed and eCommerce and electronic signatures will be covered.

Outcomes

On completion of this module, the student should be able to
- be aware of regulations concerning Multimedia and Information Systems on national and European level
- understand the principles of public regulation and aspects of liability concerning new media applications and Information Systems
- discuss the aspects of protection of intellectual property as far as Internet Technologies and Information Systems are concerned
- be aware of the importance and legal consequences of security issues and be able to act accordingly
- recognize and understand the risk of penal acts.

Recommended Literature

Since this is a rapidly changing field some of the newer literature will be announced during the lectures. Here are a few example books on the field:
Walden/Angel (ed.), Telecommunications law and regulation, 2nd ed., Oxford, Oxford Univ. Press 2005
Smith, Internet Law and regulation, 3rd ed., London, Sweet & Maxwell 2002
Lessig, Code Version 2.0, New York, Basic Books 2006
Piepenbrock/Schuster (ed.), German Telecommunication Law and the New European Regulatory Framework, Köln, Verlag Otto Schmidt 2002
Merges/Menell/Lemley, Intellectual Property in The New Technological Age, 4th ed., New York, Aspen publishers. 2007
Lemley/Menell/Merges/Samuelson, Software and Internet Law, 3rd ed., New York, Aspen publishers 2006
Campbell (ed.), Law of international on-line business, London, Sweet & Maxwell 1998
Ramberg, Internet Marketplaces, Oxford University Press, Oxford 2002
Mason, Electronic Signatures in Law, 2nd ed., Haywards Heath, Tottel publishers 2007
Reed, Internet Law: Text and Materials (Law in Context), 2nd ed., Cambridge University Press 2004.

Recommended Prerequisite Knowledge

none

Teaching Methods

Slide presentation, exercises, discussions

85 4.03 Information and Communication Management in a Web Society

Lecturer	Prof. Dr. Robra-Bissantz, Susanne (Braunschweig)
Weekly Composition	1L + 2E
ECTS	5
Working Hours (presence/self-study)	28 / 97
Exam ID	4030
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25min)
Semester	Summer

Description

The course deals with selected Topics in the field of using Information, Communication and Cooperation as a strategic ressource or a strategic weapon from a business perspective. In a learning by teaching setting students work on the basics of a new web society and its impacts on information management, knowledge management, process management and communication management. In biweekly meetings these basics are deapened. Additionally specialised learning sequences deal with case studies, discussions of latest topics or special theories.

Outcomes

After completition of this module students should
- be aware of the role of cooperation and surrounding conditions in information and communication management of companies
- know basic theories and principles of dealing with new societal principles in different fields
- be able to master dedicated concepts of a web society in information and communication management of an organization
- have the expertise and competence to handle business problems in the covered fields, to develop concepts and to reflect and discuss them.

Recommended Literature

Jarvis, J., 2011: Public Parts. How Sharing in the Digital Age Improves the Way we Work and Live, New York.
Shirky, C., 2010: Cognitive Surplus. Creativity and Generosity in a Connected Age, New York.
Weinberger, D., 2007: Everything Is Miscellaneous. The Power Of The New Digital Disorder, Times Books.

Recommended Prerequisite Knowledge

none

Teaching Methods

Co-Teaching, Blended Learning

86 4.04 Cooperate Communications 2.0

Lecturer	Prof. Dr. Robra-Bissantz, Susanne (Braunschweig)
Weekly Composition	6 Modules - about every second week
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	4020
Exam Type	Oral Presentation
Exam Duration	Written (120 min) / Oral (25min)
Semester	Winter

Description

Coporate Communications 2.0 deals with the communication of a company with its partners from a business perspective. Here the basic principles from communication to cooperation are taught as well as implications of technology - from websites to web 2.0.
Some topics are cooperation concepts in business, social media marketing, innovation and knowledge management and impacts of a web society.

Outcomes

After completition of this module students should
- be aware of the role of communication of a company with its partners, e. g. employees or customers
- know basic theories and principles of communication, coordination and cooperation
- be able to judge the differences in communication and cooperation that come with the changes of technology, e. g. web 2.0
- be able to master dedicated methods in designing communication and cooperation plattforms management
- have the expertise and competence to handle business problems in the covered fields, to develop concepts and to reflect and discuss them

Recommended Literature

Links, Articles and Videos provided in the blog: wi2cct.tumblr.com

Bradley, A., McDonald, M.: The Social Organization

Recommended Prerequisite Knowledge

none

Teaching Methods

Co-Teaching, Blended Learning

87 4.05 Business Intelligence

Lecturer	Prof. Dr. Mattfeld, Dirk Christian (Braunschweig)
Weekly Composition	2L+1E
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	4010
Exam Type	Written or oral exam, graded
Exam Duration	Written (60 min) or Oral (25 min)
Semester	Winter

Description

This module will give a broad overview on analytical decision making in terms of Data Warehouse modeling, online analytical processing (OLAP) functionality and fundamental principals of Data Mining. Furthermore, an introduction into the architecture and the usage of SAP Business Warehouses for OLAP applications is provided.

Outcomes

Students will be familiar with modelling, building and operating of analytical databases. They will be aware of the differences between OLAP and online transactional processing (OLTP) paradigms. In particular, they know how to build conceptual and logical data models in order to support analytical decision making, and they are familiar with standard approaches in intelligent data analysis.

Recommended Literature

D. Hand / H. Mannila / P. Smyth, Principles of Data Mining, MIT-Press, 2001
M. Berthold / D. Hand, Intelligent Data Analysis, Springer, 2004
M. Berthold / C. Borgelt / F. Höppner / F. Klawonn,
Guide to Intelligent Data Analysis: How to Intelligently Make Sense of Real Data, Springer, 2010

Recommended Prerequisite Knowledge

The students already have basic knowledge on data modeling and database operation from their Bachelor courses.

Teaching Methods

Slide presentation, exercises, discussions

88 4.06 Geo-Information Systems

Lecturer	Prof. Dr.-Ing. Busch, Wolfgang (Clausthal)
Weekly Composition	2L+1P
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	4060
Exam Type	Written or oral exam, graded
Exam Duration	Written (120 min) / Oral (25 min)
Semester	Winter

Description

The module gives a broad introduction into geo-information systems covering the following topics:
- Introduction (definitions, purpose of GIS, problem solving using GIS, applications, software packages)
- Geographic information and spatial data (real world representation, spatial phenomena, spatial representation, topology, spatial data structures, data types, references frames)
- Data capture (data input, data preparation, data quality)
- GIS Functionality (basic maintenance functions, buffer, overlay and intersection, topological analyses and network operations).

The module includes practical exercises using ArcGIS 9.0 (or similar).

Outcomes

On successful completion of this module student have acquired basic knowledge about modeling of geological objects, design and functionality of geo-information systems, performance of spacial analyses and visualization of results, and are able to utilize geo-information systems.

Recommended Literature

- Bernhardsen: Geographical Information Systems, Wiley 2002
- DeMers: Fundamentals of Geographic Information Systems, Wiley 2005
- Worboys, Duckham: GIS. A computing perspective. CRC Press 2004

Recommended Prerequisite Knowledge

none

Teaching Methods

Beamer presentation, whiteboard, practical lab exercises

89 4.07 Electronic Business

Lecturer	Prof. Dr. Robra-Bissantz, Susanne (Braunschweig)
Weekly Composition	2L+1E
ECTS	3
Working Hours (presence/self-study)	60/30
Exam ID	
Exam Type	Oral Presentation
Exam Duration	20
Semester	Winter

Description

Foundations of a operational Information Management. Concepts, technologies and application system for operational tasks
Operational Areas:
- Processmanagement
- Knowledge Management
- Information Management, and others
intercorporate Areas:
- E-Commerce
- E-Procurement
- Market Engineering

Outcomes

Students understand the role of information in the context of operational tasks, people and technology. They know basic concepts and application systems for communication and coordination and focus here either in-house (eg. as in process and knowledge management) or operational area (eg. as in ECommerce and in electronic markets). Here they acquire technical and methodological knowledge and skills, which put them in a position to expand their knowledge independently, and apply existing knowledge to the team in a project environment to solve practical problems limited.

Recommended Literature

Bodendorf, F., Robra-Bissantz, S.: E-Business-Management, Berlin 2009

Laudon, K. et al.: Wirtschaftsinformatik: Eine Einführung, München 2006

Kollmann, T.: E-Business: Grundlagen elektronischer Geschäftsprozesse in der Net Economy, Wiesbaden 2008

Recommended Prerequisite Knowledge

Teaching Methods

Lecture and group work

90 5.01 Courses in Soft Skills

Lecturer	Studiendekan, ITIS (Clausthal)
Weekly Composition	varies
ECTS	5
Working Hours (presence/self-study)	42 / 83
Exam ID	5040
Exam Type	Ungraded
Exam Duration	n.a.
Semester	Summer and Winter

Description

The students acquire key competences in important non-technical areas such as self-organization, communication and language skills, project management, and others.

Courses for this module can be chosen from offers awarding credit points by the following institutions:

Hannover:
Arbeitsbereich Schlüsselkompetenzen (ZfSK), http://www.zfsk.uni-hannover.de
Fremsdprachenzentrum (FSZ), http://www.fsz.uni-hannover.de/

Göttingen:
Zentrale Einrichtung für Sprachen und Schlüsselqualifikationen (ZESS), http://www.zess.uni-goettingen.de/
Fakultätsübergreifende Schlüsselqualifikationen: http://www.uni-goettingen.de/de/196175.html

Braunschweig:
Career Service, Soft skill offers, https://www.tu-braunschweig.de/career/studierende/softskills
Sprachenzentrum, https://www.tu-braunschweig.de/sprachenzentrum

Clausthal:
Internationales Zentrum Clausthal (IZC), http://www.izc.tu-clausthal.de/

Sample courses:
- Project Management in an International Context
- German as a foreign language/Deutsch für Austauschstudierende (Stufen A1-B2)
- Intercultural Communication

Outcomes

On completion, students can apply the acquired skills and methods to their studies and project work, can transfer the acquired competences to other contexts, and can further develop these competences independently on their own.

Recommended Literature

depends on selected courses

Recommended Prerequisite Knowledge

none

Teaching Methods

presentation, discussion

91 6.01 Research Project

Lecturer	Studiendekan, ITIS (Clausthal)
Weekly Composition	n.a.
ECTS	30
Working Hours (presence/self-study)	depends on individual arrangements
Exam ID	
Exam Type	Written Report and Oral Presentation
Exam Duration	depends on individual agreement
Semester	Every Semester

Description

The student is embedded within a research team in one of the ITIS institutes. Under the guidance of experiences researchers, the student is responsible for performing research within that project on her own responsibility. This includes all relevant research activities from literature surveys, design and development of algorithms, prototype implementation, scientific evaluation, to actually producing and submitting research publications.
The research project spans 30 credit points. The suggested distribution of credit points is 10 for the 2nd semester and 20 for 3rd semester (this is also assumed for the suggested schedule in the following description), but it is also possible to do the complete 30CP in the 3rd semester, for example, with an appropriately modified schedule.
Registration:
The project module is registered by filling out the appropriate project module registration template, similar to the registration of the M.Sc. thesis. The template contains information about the context, i.e. the research project for which this module is contributing, responsible advisor, about the research plan with motivation and problem statement, methodology and experimental setup (if applicable), as well as a short list of relevant references. The registration needs to be signed by the student and advisor and is send to the examination office.

Outcomes

The aim of the project module is to teach the students how to perform research in a guided scientific way, in the context of a research project currently being performed in the hosting ITIS research group. Under supervision of a mentor who is a lead researcher, the students learn the state of the art in their field that also includes literature review, performing and evaluating research tasks. Further, they also acquire their skills in (team) communication and presentation as well as obtaining their experience in technical and theoretical methods.

The outcome (in terms of documents) of this module are as follows:
The students have to provide a technical report. Furthermore, it is recommended that the student writes a research paper in collaboration with the advisor which should be submitted as a workshop (or conference) paper. This is not required for passing the project. If such a paper is written, the technical report may be based heavily on that publication.
Furthermore, in order to conclude this module, two ungraded presentations have to be performed (one

intermediate presentation and one end presentation). These presentation should be held during the ITIS Research or Welcome Day and can either be oral presentation or poster presentations (as recommended by the advisors). If there are no time slots available during these two events, individual presentation date can be agreed upon.

Recommended Literature

Literature is provided by the hosting research institute. Also, the institute will recommend / demand the successful participation in lectures or seminars matching the research topic worth 20 credits.

Recommended Prerequisite Knowledge

none

Teaching Methods

scientific project work, mentoring

92 6.02 Master Thesis

Lecturer	Studiendekan, ITIS (Clausthal)
Weekly Composition	n.a.
ECTS	30
Working Hours (presence/self-study)	depends on individual arrangements
Exam ID	
Exam Type	Master Thesis
Exam Duration	-
Semester	Every Semester

Description

Within the master thesis, the student proves his or her ability to perform independent research on his or her own.
Topics should address current research issues within the field of internet technologies or information systems.

Outcomes

If performed sucessfully, students have proven themselves as capable and competent young researchers. This includes:
- Formalization of a scientific topic
- self-guided literature exploration
- Solving of scientific problems
- Evaluating solutions
- Discussing results
- Presenting scientific works

Recommended Literature

Thesis topic specific literature.

Recommended Prerequisite Knowledge

none

Teaching Methods

scientific project work, mentoring