Module Catalog

B.Sc. Information Engineering
Academic Programs Heilbronn
Technische Universität München

www.tum.de/

Please note:
The language course offerings have been removed from this document.
You can find the language course offerings in a separate file.

Module Catalog: General Information and Notes to the Reader

What is the module catalog?
One of the central components of the Bologna Process consists in the modularization of university curricula, that is, the transition of universities away from earlier seminar/lecture systems to a modular system in which thematically-related courses are bundled together into blocks, or modules.
This module catalog contains descriptions of all modules offered in the course of study.
Serving the goal of transparency in higher education, it provides students, potential students and other internal and external parties with information on the content of individual modules, the goals of academic qualification targeted in each module, as well as their qualitative and quantitative requirements.

Notes to the reader:

Updated Information
An updated module catalog reflecting the current status of module contents and requirements is published every semester. The date on which the module catalog was generated in TUMonline is printed in the footer.

Non-binding Information
Module descriptions serve to increase transparency and improve student orientation with respect to course offerings. They are not legally-binding. Individual modifications of described contents may occur in praxis.
Legally-binding information on all questions concerning the study program and examinations can be found in the subject-specific academic and examination regulations (FPSO) of individual programs, as well as in the general academic and examination regulations of TUM (APSO).

Elective modules
Please note that generally not all elective modules offered within the study program are listed in the module catalog.

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Required Module Advanced Seminar Course | Pflichtmodul Seminar

Module Description

INHN0015: Bachelor Advanced Seminar Course | Bachelor-Seminar

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 120	**Contact Hours:** 30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Type of Assessment: Research elaboration
Before the start of the Seminar (usually at the end of the previous semester) each participant receives an advanced topic on which she prepares a scientific essay by using scientific literature which has possibly been found on her own.
The length of the scientific essay varies according to the topic.
The results of the work will be presented to the other participants of the seminar in oral form, supported by visual media such as projector or slides. Evaluated is also how the student responds to questions, suggestions and discussion points to her work and presentation, and how she takes part in the discussion on the work and presentations of other participants. By that students demonstrate their expertise for critical analysis of presented scientific contents.
Before the start of the seminar the respective lecturer will announce, how the various ingredients are weighted for the calculation of the module grade.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
First 3 terms of the Bachelor's Program

Content:
- Independent assessment of a advanced scientific theme
- Preparation of a term paper with a section on related work
- Presentation and discussion of scientific results

Intended Learning Outcomes:
Participants have the necessary methodological and interdisciplinary skills to independently write a scientific essay about an advanced topic in computer science, as well as to present and discuss its content. The students can work with scientific literature (i.e. search, categorize, prioritize, cite, ...). They master the required presentation and discussion techniques.

Teaching and Learning Methods:
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Media:
Beamer, slides, whiteboard, report, possibly tool presentation and/or animations

Reading List:
Scientific publications to the given topic

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar Knowledge Graphs (IN0014, IN45076) (Seminar, 2 SWS)
Acosta Deibe M

Seminar Knowledge Graphs (INHN0015, INHN4006) (Seminar, 2 SWS)
Acosta Deibe M [L], Acosta Deibe M, Ke J, Schwabe T

Seminar High-Performance Computing (INHN0015, INHN4007) (Seminar, 2 SWS)
Anzt H

Seminar Automated Mobile App Testing (INHN0015, INHN4010) (Seminar, 2 SWS)
Chen C

Seminar Security of Large Language Models (LLMs) (INHN0015, INHN4012) (Seminar, 2 SWS)
Chen C

Seminar: Large Language Models (INHN0015, INHN4009) (Seminar, 2 SWS)
Fraser A [L], Di Marco M, Fraser A

Seminar AI-Empowered Automated Software Development (INHN0015, INHN4013) (Seminar, 2 SWS)
Gu W

Seminar - Computer Networking & Internet (INHN0015) Campus Heilbronn (Seminar, 2 SWS)
Günther S [L], Günther S

Seminar Hot Topics in BPM Research (INHN0015, INHN4005) (Seminar, 2 SWS)
Khraiwesh S, Pufahl L

Bachelorseminar Algorithm Engineering (INHN0015, INHN4014) (Seminar, 2 SWS)
Kobourov S [L], Kobourov S, Miller J

Seminar Exploratory Software Testing (INHN0015, INHN4016) (Seminar, 2 SWS)
Su Y

Bachelor Seminar: History of Computer Science (INHN0015, INHN4017) (Seminar, 2 SWS)
Trinitis C [L], Anzt H, Luttenberger M

Seminar Software Engineering for Artificial Intelligence (INHN0015, INHN4008) (Seminar, 2 SWS)
Wagner S [L], Eris H, Habib M, Habiba U
For further information in this module, please click campus.tum.de or here.

Required Module Bachelor Practical Course | Pflichtmodul Bachelor-Praktikum

Module Description

INHN0021: Bachelor Practical Course | Bachelor-Praktikum

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 10	**Total Hours:** 300	**Self-study Hours:** 210	**Contact Hours:** 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Type of assessment: project work
The participants in teams will handle different phases of a software project. Individual teams may deal with only one or more selected phases of the project. By their work, the participants demonstrate that they can deal with a given project contract or subcontract within a given time and using appropriate tools in teams. During design and implementation, they demonstrate that they are able to apply methods and models of engineering. They can assess the risks and problems in the various phases of a software project and are able to deal with these difficulties. A written report is prepared and possibly presented orally in order to evaluate the communicative competence in documentation and presentation of results.
Oral presentations last from 10 to 20 minutes.
Written elaborations may vary in size, but should not exceed 10 pages.
The evaluation of the artefacts created, the evaluation of the cooperation in the teams as well as the written or oral presentations of the results flow into the grading.
This practical course is offered by several lecturers with different didactic concepts.
Before the start of the practical course the respective lecturer will announced which components are to be developed and how the individual components are weighted in the calculation of the module grade.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
INHN0006 Introduction to Software Engineering, INHN0011 Fundamentals of Databases, INHN0007 Operating Systems and System Software, INHN0012 Computer networking and IT security, basic programming skills

Content:
- Implementation of a software project or subproject in teams
- Methods and models of engineering for software development in various areas of informatics
- Techniques for documentation and presentation of results or intermediate results in software development

This module is offered by different chairs. The chairs select the topic for the projects based on their research and education preferences (e.g., databases, information systems, networks, groupware, graphics, robotics, image recognition).

Intended Learning Outcomes:
Participants are able to design and implement small software systems in a team. They know how to apply engineering methods and models from different areas of informatics in order to realice the various phases of the projct. They can judge the risks and typical problems encountered in software projects and know methods to cope with these. They are able to report about their projct work in written as well as oral form.

Teaching and Learning Methods:
Participants exercise systematic software engineering for a small system in small teams with a precise task description with tight time constraints (design, implementation, test). Intermediate results of the team work have to be presented. Design, project plans and implementation have to be documented.

Media:
Beamer, slides, whitebord, platform for collaborative work, software development environment

Reading List:
Dedicated literature according to the topic

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Bachelor-Praktikum (INHN0021, INHN4052) Duckietown (Praktikum, 6 SWS)
Abdelhafez A

Bachelorpraktikum Applied Machine Learning (IN0012, IN4396) (Praktikum, 6 SWS)
Abdelhafez A

Bachelor Practical Course (INHN0021, INHN4056): Data Engineering (Praktikum, 6 SWS)

Acosta Deibe M [L], Acosta Deibe M, Ke J, Schwabe T

Bachelor Practical Course Projects in Natural Language Processing (INHN0021, INHN4057) (Praktikum, 6 SWS)
Dementieva D, Fraser A, Okabe S

Bachelor-Praktikum (INHN0021, INHN4053) Ilab (Praktikum, 6 SWS)
Günther S

BS Practical Course on Network Visualization for Competitive Challenges (INHN0021, INHN4062) (Praktikum, 6 SWS)
Kobourov S [L], Brand T, Förster H, Kobourov S, Miller J, Wallinger M, Zink J

BS Practical Course on Algorithm Design for Competitive Challenges (INHN0021, INHN4060) (Praktikum, 6 SWS)
Kobourov S [L], Förster H, Kobourov S, Miller J, Wallinger M, Zink J

Bachelorpraktikum Human-Centered Artifact Design (INHN0021, INHN4061) (Praktikum, 6 SWS)
Leiser F, Armbruster K, König D, Neß N

Bachelor Practical Course (INHN0021) Building a BPM Research App - Campus Heilbronn (Praktikum, 6 SWS)
Pufahl L [L], Andree K, Bein L, Pufahl L

Bachelorpraktikum Next Gen Programming (INHN0021, INHN4059) (Praktikum, 6 SWS)
Wagner S [L], Eisenreich T, Habib M

Bachelor Practical Course (INHN0021, IN0012, INHN4055): Optimization, maintenance and further integration into the TUM ecosystem of the TUM MGT Chatbot (Praktikum, 6 SWS)
Wagner S [L], Wagner S
For further information in this module, please click campus.tum.de or here.

Required Modules Informatics | Pflichtmodule Informatik

Module Description

INHN0001: Introduction to Informatics | Einführung in die Informatik

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Type of Assessment: exam (120 minutes)

The exam takes the form of 120 minutes written test. Questions allow to assess acquaintance with concepts of Informatics and programming, small programming tasks assess the ability to conceive appropriate algorithmic solutions and realize concurrent applications.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Participants should attend "Fundamentals of Programming (Exercises & Laboratory)" at the same time.

Content:
The module is concerned with topics such as:
- Introduction
++ Basic notions: Problem - algorithm - program
++ Imperative programming constructs
- Syntax and semantics
++ Syntax of programming languages: regular expressions and contextfree grammers
++ Semantics of programs: control-flow graphs
- Basic data structures I
++ Numbers, strings, arrays
++ Insertion sort
- Recursion

++ Binary search
++ Patterns of recursion
- Basic data structures II
++ Objects, classes, methods
++ Lists, stacks, queues
- Object-oriented programming
++ Inheritance
++ Abstract classes and interfaces
++ Polymorphism
- Programming in the large (perspectives)
- Concurrency and Threads

Intended Learning Outcomes:
Upon successful completion of the module participants understand the essential concepts of computer science on a fundamental, practice-oriented, but scientific level.
Concepts of this kind are for example: Algorithms, syntax and semantics, as well as efficiency in terms of memory consumption or time.
Participants are then able to solve well-posed algorithmic problems and to implement basic distributed and concurrent applications in Java or a similar object-oriented language. They understand the underlying concepts and models and are therefore able to acquire skills in other imperative and object-oriented programming languages on their own.

Teaching and Learning Methods:
Lecture combined with experimental assessment of examples at the computer and evaluation of further readings.

Media:
Slide show, blackboard, online programming experiments, animations, lecture recording

Reading List:
Heinisch, Müller-Hofmann, Goll: Java als erste Programmiersprache, Teubner, 2007
Deitel, Harvey / Deitel, Paul: How to program Java Prentice-Hall, 2002
Flanagan, David: Java in a Nutshell O'Reilly, 2002
Bishop, Judith: Java gently Prentice-Hall, 2001
Eckel, Bruce: Thinking in Java Prentice-Hall, 2002

Responsible for Module:
Wagner, Stefan; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Einführung in die Informatik (INHN0001) Campus Heilbronn (Vorlesung, 4 SWS)
Wagner S [L], Wagner S, Berrezueta Guzman J
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0002: Fundamentals of Programming (Exercises & Laboratory) | Praktikum: Grundlagen der Programmierung

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Type of Assessment: exercise work
On 7 to 14 exercise sheets questions or programming tasks will be posed, which have to be solved and handed in by the participants in written or electronic form. By that participants approve that they are able to do programming in the small by means of an object-oriented programming language such as Java and that they have understood fundamental concepts of Informatics and are able to apply these in order to provide original solutions or programs. In order to identify the individual contributions of the participants they must be able to defend their solutions interactively. Before the beginning of classes, it shall be announced how the single exercise sheets contribute to the final grade.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Participants should attend "Introduction to Informatics 1" at the same time.

Content:
Accompanying the module IN0001, assignments may excercise and apply for problem solving concepts, such as:
- basic data structures
- recursion
- objects, classes and methods
- lists, queues, and trees
- advanced concepts of object-oriented programming
- concurrency

Intended Learning Outcomes:
After successful completion of the module, participants are acquainted with the programming language Java or a similar object-oriented programming languae and master programming in the small. They are able to realize programs on their own and to apply the fundamental concepts of Informatics as taught in module IN0001, on a basic practical but scientific level.

Teaching and Learning Methods:
Approximately a quarter of the module consists of the processing of exercises for the accompanying module IN0001.
These exercises deepen the understanding of fundamental concepts of computer science. During the remainder of the time, the participants develop small sample applications under guidance to develop their programming skills in an object-oriented programming language.

Media:
Beamer, slides, whitebord, software development environment

Reading List:
See module INHN0001

Responsible for Module:
Wagner, Stefan; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Grundlagen der Programmierung (INHN0002) Campus Heilbronn (Praktikum, 4 SWS)
Wagner S [L], Berrezueta Guzman J, Wagner S
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0003: Introduction to Computer Organization and Technology - Computer Architecture | Einführung in die Rechnerarchitektur

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 8	**Total Hours:** 240	**Self-study Hours:** 150	**Contact Hours:** 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination will be conducted in written form as part of a 120 minute exam. Here, examples from different areas of machine oriented programming in Assembler, micro-programming, circuit design and hardware description languages will be used to assess the capability of the students to master such concepts of computer architectures. Answers to short questions about basic concepts in computer architecture must show that the candidates mastered these concepts. Support material is provided during the examination, no additional help is allowed.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
None

Content:
- Computer systems: basic architecture and organization: Von- Neumann-Computer, machine-instruction cycle, hardware-software interface
- The Instruction Set Architecture (ISA): functionality and machineoriented Assembler programming
- Micro-programmed implementation of machine instructions
- Circuits, sequential circuits, circuit design with a formal language using the example of VHDL
- Introduction to computer architecture: microprocessor architectures and systems, parallel and distributed systems,
memory systems, I/O

Intended Learning Outcomes:
After attending this module students are able to understand computer systems as layered abstract machines. They get a first impression of the area of computer architectures and possess the following abilities:
They have learned to apply the main concepts of machine-oriented programming, microprogramming and circuit design. They understand the machine instruction cycles based on the underlying hardware at the register transfer level and they are able to classify computer architectures. The understand the basics of modern computer architecture.

Teaching and Learning Methods:
Using slide decks with animations, the lecture explains the basic concepts of computer architecture. This is supported by a concurrent series of central exercise sessions as well as small tutor groups, which explain the application of the material presented in the class. Homework allows the students to self-study the material. Solutions are then discussed both in the central exercise class as well as the smaller tutor groups. The ability to present their own solution as part of the tutor groups further aids in the understanding of the material and supports the students' ability to communicate.

Media:
Slides of lectures, exercise sheets with assignments, collections of assignments, other working material.

Reading List:
- Andrew S. Tanenbaum, Todd Austin: Rechnerarchitektur: Von der digitalen Logik zum Parallelrechner
- David A. Patterson, John L. Hennessy, Computer Organization and Design: The Hardware/ Software Interface
- Intel386 TM DX MICROPROCESSOR 32-BIT CHMOS MICROPROCESSOR WITH INTEGRATED MEMORY
MANAGEMENT
- Beschreibung der mikroprogrammierbaren Maschine

Responsible for Module:
Trinitis, Carsten; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Einführung in die Rechnerarchitektur (INHN0003) (Vorlesung, 4 SWS)
Trinitis C [L], Trinitis C

Übungen zu Einführung in die Rechnerarchitektur (INHN0003) (Übung, 2 SWS)
Trinitis C [L], Trinitis C
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0006: Introduction to Software Engineering | Einführung in die Softwaretechnik

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Type of assessment: written exam
The exam takes the form of a 90 minutes written test. The examination consists of describing the main concepts and methods of each phase of the software engineering process. The students have to apply their knowledge to solve small problems. By means of modelling problems, the students have to show their ability to adequately analyze and evaluate given requirements.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Fundamentals of Programming (Exercises & Laboratory)

Content:
Software engineering is the the establishment and systematic use of engineering principles, methods, and tools for the division of work, the development and application of extensive, complex software systems. It deals with the production and development of software, the organization and modelling of data structures and objects, and the operation of software systems. Topics of the lecture include, among others:
- Modeling with UML
- Process models in software development (linear, iterative, agile)
- Requirements elicitation and analysis (functional model, dynamic model, and object model)
- System design (specification, software architecture, architectural patterns, and design goals)
- Object design and implementation (reuse, design patterns, and interface specification)
- Testing (component test, integration test, and system test)
- Configuration management, build management, and release management
- Software maintenance and evolution

- Project organization and communication

Intended Learning Outcomes:
After successful completion of this module, students are familiar with the basic concepts and methods of the different phases of a project, e.g. modeling the problem, reuse of classes and components, and delivery of the software. They have the ability to select and apply suitable concepts and methods for concrete problems.
The students know the most important software engineering terms and workflows and are able to analyze and evaluate given problems. In addition, students can solve concrete problems in software engineering, e.g. with the help of design patterns.

Teaching and Learning Methods:
By means of a slide presentation with animations, the interactive lecture introduces the basic concepts and methods of software engineering and explains them using examples. Small exercises, e.g. quizzes, modelling, and programming tasks, with individual feedback help students to identify whether they have understood the basic concepts and methods.
Accompanying tutorials deepen the understanding of the concepts explained in the lecture by means of suitable group exercises and show the application of the different methods with the help of manageable problems in the different phases of software engineering. Homework enables students to deepen their knowledge in self-study. The presentation of the own solution in the accompanying tutorials improves communication skills, which are essential in software engineering. Individual feedback on homework allows students to measure learning progress and improve their skills.

Media:
Media formats:
Lecture with digital slides, livestream, online exercises (programming, modeling, quiz) with individual feedback, discussion forum and communication platform for the exchange between instructors, tutors, and students

Reading List:
B. Bruegge, A. Dutoit: Object-Oriented Software Engineering: Using UML, Design Patterns and Java, 3rd Edition, Pearson Education, 2010
I. Sommerville, Software Engineering, 9th edition, Addison Wesley, 2010

Responsible for Module:
Wagner, Stefan; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Einführung in die Softwaretechnik (INHN0006) Campus Heilbronn (Vorlesung, 3 SWS)
Wagner S

Übungen zu Einführung in die Softwaretechnik (INHN0006) Campus Heilbronn (Übung, 2 SWS)
Wagner S [L], Berrezueta Guzman J, Habiba U

For further information in this module, please click campus.tum.de or here.

Module Description

INHN0007: Operating Systems and System Software | Betriebssysteme und Systemsoftware

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In the 90 minutes written exam students have to show their understanding of the subjects, like resource management and the usage of systems software. They have to prove to be able to identify a given problem and find solutions within limited time.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Introduction to Informatics 1 and Introduction to Computer Organization and Technology – Computer Architecture are recommended

Content:
Basic concepts: Operating systems; concurrency; parallel programming; low-level programming (processes, memory, communication, resource management; models (abstract, formal) for concurrency, e.g. petri nets; mutual exclusion, synchronization, deadlocks; compiler/linker/loader with library integration, transition to (adequate) hardware basic, machine-oriented programming and C; I/O especially as preparation for networking)

Intended Learning Outcomes:
After visiting this module, students are able to understand the basics, problems and solutions of operating systems and current developments. In addition they understand the components like process and memory management and they are able to analyze and evaluate different strategies and techniques. They learn to apply the acquired basic knowledge to new developments in the area of operating systems as well as system software.

Teaching and Learning Methods:
By means of a slide presentation, the lecture introduces the basic concepts and methods of operating systems and explains them using examples.
Accompanying tutorials deepen the understanding of the concepts explained in the lecture by means of suitable group exercises and show the application of the different methods with the help of manageable problems in the different aspects of operating system decomposition.
Additional programming exercises enable students to deepen their knowledge in self-study.
Feedback and help in programming tutoring sessions allow students to measure learning progress and improve their skills.

Media:
Slides and further documents via moodle

Reading List:
A.S. Tanenbaum, H. Bos: Modern Operating Systems, 4/E (Pearson, 2015)

Responsible for Module:
Trinitis, Carsten; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Übungen zu Grundlagen: Betriebssysteme und Systemsoftware (INHN0007) Campus Heilbronn (Übung, 2 SWS)
Trinitis C [L], Trinitis C

Grundlagen: Betriebssysteme und Systemsoftware (INHN0007) Campus Heilbronn (Vorlesung, 3 SWS)
Trinitis C [L], Trinitis C
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0008: Fundamentals of Algorithms and Data Structures | Grundlagen: Algorithmen und Datenstrukturen

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 150 minutes written test. In the written exam, based on the questions posed, the students are intended to demonstrate that they have fundamental knowledge in the area of algorithms and data structures. They are able to apply their knowledge successfully in order to solve given problems. In addition, by answering the questions, the students are expected to show that they have profound knowledge of the fundamental algorithmic methods and data structures covered in the module. The students prove that they are able to recognize and analyze basic algorithmic problems and to find efficient solutions within a limited scope of time.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0001 Introduction to Informatics, INHN0004 Discrete Structures

Content:
First, the module studies the basics of efficiency and complexity analyses. Basic terminology, complexity measures, the Landau symbols and different machine models are introduced. Then, fundamental data structures and algorithmic problems are studied.
- Data structures for sequences: Dynamic arrays, lists, stacks and queues are investigated. The complexity of each operation is analyzed.
- Hashing: Hashing with chaining, universal hashing as well as various probing methods are examined. Perfect hashing and hash-based algorithms, e.g. for set intersection problems, may also be explored.
- Sorting: First, simple algorithms such as InsertionSort, SelectionSort and BubbleSort are reviewed. Then, advanced algorithms such as MergeSort, HeapSort and QuickSort are

investigated. Furthermore, sorting-based algorithms, the lower bound for comparison-based sorting, selection, RadixSort and external sorting may be covered.
- Priority queues: Binary heaps and binomial heaps are presented in the module.
- Search trees: Binary search trees, AVL trees and (a,b)-trees are investigated.
- Graph algorithms: Various graph representations, traversal techniques using DFS/BFS, the computation of 2-connected components and strongly connected components, topological sorting, the computation of the shortest paths and minimum spanning trees are covered. Approaches for solving the Traveling Salesman Problem (TSP) may be studied.
The module may also cover data compression schemes (Huffman, Lempel-Ziv) and simple pattern matching algorithms.

Intended Learning Outcomes:
The participants master the basic algorithms and data structures mentioned above. They are able to independently analyze their complexity and apply the corresponding analysis concepts to related algorithmic problems. Furthermore, the participants are able to use the algorithms and data structures handled, if necessary to modify them and to compare different solutions in their quality.

Teaching and Learning Methods:
The module consists of lectures and tutorials. The content of the lectures is conveyed in presentations of the scientific material. By solving homework assignments, the students are encouraged to work intensively on the respective topics. The solutions of the assignments are discussed in the tutorials. The homework assignments are graded so that students get an individual feedback on their learning success.

Media:
Slides, whiteboard, homework assignments

Reading List:
Kurt Mehlhorn, Peter Sanders: Algorithms and Data Structures - The Basic Toolbox. Springer, 2008.
Vertiefendes und ergänzendes Material zur Vorlesung findet sich in folgenden Büchern:
- Volker Heun: Grundlegende Algorithmen - Einführung in den Entwurf und die Analyse effizienter Algorithmen. 2.
Auflage, Vieweg, 2003.
- Michael T. Goodrich, Roberto Tamassia. Algorithm Design - Foundations, Analysis, and Internet Examples. John
Wiley & Sons, 2002.
- Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein. Introduction to Algorithms, 3rd edition,
MIT Press, 2009. Deutsche Übersetzung: Algorithmen - Eine Einführung. 3. Auflage, Oldenbourg Verlag, 2010.
- Jon Kleinberg, Eva Tardos. Algorithm Design. Pearson Education, 2005.
- Uwe Schöning. Algorithmik. Spektrum Akademischer Verlag, 2001.
- Robert Sedgewick, Kevin Wayne: Algorithms. 4th edition, Addison-Wesley, 2011.

- Robert Sedgewick. Algorithms in Java, Parts 1-4. 3rd edition, Addison-Wesley, 2002. Deutsche Übersetzung: Algorithmen in Java, Teil 1-4. 3. Auflage, Pearson Education, 2003.

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Grundlagen: Algorithmen und Datenstrukturen (INHN0008) (Vorlesung, 5 SWS)
Brand T, Kobourov S, Luttenberger M, Miller J

Übungen zu: Grundlagen: Algorithmen und Datenstrukturen (INHN0008) (Übung, 2 SWS)
Brand T, Kobourov S, Luttenberger M, Miller J
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0011: Fundamentals of Databases | Grundlagen: Datenbanken

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The academic assessment will be done by a 90 minutes written exam. Assignments checking knowledge verify the familiarity with the main concepts of relational database systems. Transfer assignments and small scenarios check the ability to apply and evaluate these concepts systematically and in a qualified manner.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0004 Discrete Structures, INHN0001 Introduction to Informatics

Content:
SQL, data integrity, theory of relational database design, physical data organisation (storage structures, index structures), query processing, transaction management, main features of error handling (recovery, backup) and multiuser synchronisation, security aspects (authorization), XML data modeling (optional); in the tutorial the content is practiced along concrete examples

Intended Learning Outcomes:
Students are able to apply the essential concepts of relational database systems and can use and evaluate them systematically and in a qualified manner.
The students have the expertise to systematically use a database system starting from the conceptual design to the implementation design to the physical design. They are able to formulate even complex queries in SQL and have a basic understanding of logical and physical optimization based on relational algebra. Furthermore they know how to safe-guard a database application with respect to recovery, concurrency control and authorization.

Teaching and Learning Methods:
Lecture, tutorial, problems for individual study, web interface to the data base system HyPer for actively testing SQL queries and self-study of query plans

Media:
Lecture with animated slides

Reading List:
- Alfons Kemper, André Eickler: Datenbanksysteme. Eine Einführung. 10., aktualisierte und erweiterte Auflage,Oldenbourg Verlag, 2015
- A. Kemper, M. Wimmer: Übungsbuch: Datenbanksysteme. 3. Auflage Oldenbourg Verlag, 2012
- A. Silberschatz, H. F. Korth, S. Sudarshan: Database System Concepts. Sixth Edition, McGraw-Hill, 2010

Responsible for Module:
Acosta Deibe, Maribel; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Grundlagen: Datenbanken (INHN0011) Campus Heilbronn (Vorlesung, 3 SWS)
Acosta Deibe M [L], Acosta Deibe M

Übungen zu Grundlagen: Datenbanken (INHN0011) Campus Heilbronn (Übung, 2 SWS)
Acosta Deibe M, Schwabe T
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0012: Computer Networking and IT Security | Rechnernetze und IT-Sicherheit

Version of module description: Gültig ab winterterm 2022/23

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 90 minutes written test. Comprehension questions and calculation tasks allow to assess acquaintance with the technologies and methods of computer networking and security, and the understanding obtained by implementation of protocol mechanisms. Calculation tasks also allow to assess the ability to determine the performance of selected computer networks and distributed
applications.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0001 Introduction to Informatics
INHN0002 Fundamentals of Programming (Exercises & Laboratory)

Content:
Computer Networking
- Physical Layer: line coding and digital modulation schemes
- Data Link Layer: media access / multiplexing, framing, addressing, error detection, switching, wireless networks
- Network Layer: IPv4/v6 including address resolution and assignment, subnetting, multicast, static and dynamic routing
- Transport Layer: connection-less vs. connection-oriented protocols and sliding window protocols (UDP/TCP), NAT, code demos and live programming (implementation of UDP/TCP-based relay chats)
- Session / Presentation Layer: connection-less vs. connection-oriented protocols from the view of the Session Layer, examples (e.g. HTTP, TLS), encoding, data compression (Huffman)

- Applicaton Layer: name resolution (DNS), case studies of various protocols such as Telnet, HTTP, FTP, SMTP, SSH, etc.
Security:
- Firewalls
- Authentication, authorization privacy, integrity
- Basics of cryptography (symmetric vs. asymmetric encryption)
- Case study of basic encryption algorithms (e.g. RC4, AES)
- Protocols with security machanisms, e.g. SSH, TLS, IPSec

Intended Learning Outcomes:
After successful completion of the module, participants understand the key concepts of technologies and methods of computer networks and security and are able to use key layered network architecture protocols to explain what protocol mechanisms are used in each layer and how they work. They understand the architecture and implementation of basic encryption algorithms and protocols and their application in computer networking.
Participants can determine the performance of selected networks and security implementations, and can implement specific protocol mechanisms.

Teaching and Learning Methods:
The interactive lecture with slide presentations, animations, demonstrations and life programming presents the basic knowledge of computer networks and security and explains them using examples. Quizzes help students to recognize whether they have understood the basic concepts and essential contexts. Accompanying tutor exercises deepen the understanding of the contents of the lecture by means of suitable tasks and show the application of the various methods on the basis of manageable problems. Programming tasks allow computeraided deepening and application of conceptual knowledge to practical problems.
A midterm examination motivates students to continuously follow the lecture.

Media:
Lecture slides, exercise sheets, demonstrations, code demos, past exams

Reading List:
Literature
There is no (single) literature covering the lecture. Taking the lecture is therefore recommended. A standard book about computer networking could be:
1. James F. Kurose, Keith W. Ross Computernetzwerke Pearson Studium; 5. aktualisierte Auflage, 2012
2. Andrew S. Tanenbaum / Prof. David J. Wetherall Computernetzwerke Pearson Studium, 5. aktualisierte Auflage, 2012

Responsible for Module:
Günther, Stephan; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Übungen zu Rechnernetze und IT-Sicherheit (INHN0012) Campus Heilbronn (Übung, 2 SWS)
Günther S [L], Günther S

Rechnernetze und IT-Sicherheit (INHN0012) Campus Heilbronn (Vorlesung, 3 SWS)
Günther S [L], Günther S
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0016: Introduction to Signal Processing | Einführung in die Signalverarbeitung

Version of module description: Gültig ab winterterm 2022/23

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Die Prüfungsleistung wird in Form einer Klausur von 105 Minuten erbracht. In dieser soll nachgewiesen werden, dass moderne Methoden der Signalverarbeitung beherrscht werden und geeignete Algorithmen für ein bestimmtes Problem ausgewählt werden können.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
None

Content:
Linear Continuous-Time Signal Processing:
Fourier methods, Laplace transform, convolution, frequency/time domain processing. Passive and active continuous filters.
Sampling and Reconstruction:
Sampling theorem, aliasing, quantization, sampled data systems, cardinal (Whitaker) reconstruction, zero-, first-, second-order hold reconstructors, interpolators, non-resetting reconstructors, matched filtering. Interpolation and decimation.
Discrete-Time Signal Processing:
The z transform, difference equations, relationship between F(z) and F*(jw), mappings between s-domain and z-domain, inverse z transform. Discrete–time stability.
Discrete Spectral Analysis:
The DFT and its relationship to the continuous FT, the FFT and implementations (decimation in time and frequency), radix-2 implementation, leakage, windowing. Uses of the DFT: convolution — (overlap and add, select savings), correlation. Random processes, power spectral density (PSD) estimation.

Numerical Simulation:
Impulse-, step-, ramp-response. Error analysis.
Filter Design:
Butterworth, elliptic, Chebyshev low-pass filters. Low-pass design methods based on continuous prototypes. Conversion to high-pass, band-pass, band-stop filters. Discrete-time filters: IIR and FIR. Linear phase filters. Frequency sampling filters.
Statistical Signal Processing:
Linear prediction, adaptive filters (LMS), recursive least-squares

Intended Learning Outcomes:
At the end of this module students are able to
• evaluate theoretical concepts and underlying algorithms of modern digital signal processing systems;
• apply fundamental mathematical tools, in particular frequency domain techniques, in the analysis and design of signal processing systems;
• design, implement and test simple digital filters according to given specifications;
• use software packages for the analysis and design of signal processing systems;
• use software packages to implement signal-processing algorithms;
• explain basic discrete-time signal and system types, convolution sum, impulse and frequency response concepts for linear, time-invariant (LTI) systems, difference equation realization of LTI systems and discrete-time Fourier transform and basic properties of these;
• understand periodic sampling of analog signals and the relation between Fourier transforms of the sampled analog signal and the resulting discrete-time signal;
• grasps z and inverse z transform, region of convergence concepts and their properties;
• perform simple transform calculations;
• understand the system function concept with its relations to impulse and frequency responses;
• understand the basic properties of system functions and frequency responses of LTI systems, minimum-phase, all-pass and linear-phase systems;
• create signal flow graph and block diagram representations of difference equations that realize digital filters;
• explain basic properties of forward and inverse discrete Fourier transform and their computation by fast algorithms.

Teaching and Learning Methods:
Lecture, exercise course, problems for individual study

Media:
Folien, Übungsblätter

Reading List:
- Janus A. Cadzow, Foundations of Digital Signal Processing and Data Analysis, Macmillan, 1987
- Johnny R. Johnson, Introduction to Digital Processing, Prentice Hall, 1989
- Rolf Unbehauen, Systemtheorie, Oldenburg, 1989
- Oppenheimer/Willsky, Signals and Systems, Prentice Hall, 1983

- A. van den Enden/N. Verhoeckx, Discrete-Time Signal Processing - An Introduction, Prentice Hall, 1989
- R. Best, Digitale Signalverarbeitung und -simulation, AT-Verlag, 1989
- John G. Proakis, Dimitris G. Manolakis, Digital Signal Processing - Principles, Algorithms and Applications, Prentice Hall, 1996
- Oppenheimer/Schafer, Discrete-Time Signal Processing, Prentice Hall, 1989
- Tamal Bose, Digital Signal and Image Processing, Wiley, 2004

Responsible for Module:
Günther, Stephan; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Introduction to Signal Processing (INHN0016) (Vorlesung, 3 SWS)
Abdelhafez A [L], Abdelhafez A, Hafez A, Mousa H, Xie P

Übungen zu: Introduction to Signal Processing (INHN0016) (Übung, 2 SWS)
Abdelhafez A [L], Hafez A, Mousa H, Xie P
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0017: Enterprise Architecture Management and Reference Models | Enterprise Architecture Management und Referenzmodelle

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 60	**Contact Hours:** 120

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination will be in the form of a written exam (120 minutes) in which the students' ability to describe, evaluate and apply models, methods, visualizations and tools of EAM and reference modeling for manageable problems in a context-dependent manner will be tested.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
None

Content:
- Motivation: Use of Enterprise Architecture Models, Reference models and Patterns to support Strategic IT Management and Digital Transformation
- Foundations of Modeling
- Enterprise Architecture Models
- Reference Models and Modeling Patterns
- Capability-based Planning
- Agile Enterprise Architecture Management
- EAM Standards, Frameworks and Notations
- Large-Scale Scaling Agile Framewoks
- Agile (IT) Program Management

Intended Learning Outcomes:
Students will have a basic knowledge of enterprise architecture

management and reference modeling, including models, methods, metrics, visualizations, and tools after taking the module. In addition, students will be able to:
- describe the business architecture, application architecture and IT infrastructure of an organization holistically and formally using
standardized notations and models.
- describe (digital) transformation processes in organizations using actual, plan, and target models and roadmaps.
- use reference models and design patternas in the process.

Teaching and Learning Methods:
ecture, tutorial, problems for individual study

Media:
Slides, Moodle, modeling, exercises

Reading List:
Hanschke, I. (2013). Strategisches Management der IT-Landschaft: Ein praktischer Leitfaden für das Enterprise Architecture Management. Carl Hanser Verlag GmbH Co KG.

Kaplan, J. D. (2005). Strategic IT portfolio management: governing enterprise transformation. PRTM.

Buckl, S., Ernst, A. M., Matthes, F., Ramacher, R., & Schweda, C. M. (2009, September). Using enterprise architecture management patterns to complement TOGAF. In 2009 IEEE International Enterprise Distributed Object Computing Conference (pp. 34-41). IEEE.

Buckl, S., Ernst, J., Lankes, A. M., Matthes (2008). Enterprise architecture management pattern catalog (version 1.0, february 2008)

Sandkuhl, K., Fill, H. G., Hoppenbrouwers, S., Krogstie, J., Matthes, F., Opdahl, A., ... & Winter, R. (2018). From expert discipline to common practice: a vision and research agenda for extending the reach of enterprise modeling. Business & Information Systems Engineering, 60(1), 69-80. Chicago

Uludag, Ö., Kleehaus, M., Caprano, C., & Matthes, F. (2018,
October). Identifying and structuring challenges in large-scale agile development based on a structured literature review. In 2018 IEEE

22nd International Enterprise Distributed Object Computing
Conference (EDOC) (pp. 191-197). IEEE.

Dikert, K., Paasivaara, M., & Lassenius, C. (2016). Challenges and success factors for large-scale agile transformations: A systematic literature review. Journal of Systems and Software, 119, 87-108.

Paasivaara, M., Behm, B., Lassenius, C., & Hallikainen, M. (2018). Large-scale agile transformation at Ericsson: a case study. Empirical Software Engineering, 23(5), 2550-2596. Chicago

Responsible for Module:
Pufahl, Luise; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Exercise Enterprise Architecture Management and Reference Models (INHN0017) (Übung, 2 SWS)
Andree K, Pufahl L

Enterprise Architecture Management and Reference Models (INHN0017) (Vorlesung, 2 SWS)
Pufahl L [L], Andree K, Pufahl L
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0018: Embedded Systems, Cyber-Physical Systems and Robotics | Embedded Systems, Cyber-Physical Systems und Robotics

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 8	**Total Hours:** 240	**Self-study Hours:** 150	**Contact Hours:** 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 120 minutes written test.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0001 Introduction to Informatics, INHN0004 Discrete Structures, INHN0009 Computational Mathematics 1: Linear Algebra, INHN0014 Computational Mathematics 2: Calculus, INHN0013 Information Theory and Theory of Computation

Content:
The design of a cyber-physical system requires understanding of the controller’s architecture but also knowledge to handle the right integration of this controller with the sensors and actuators of the physical system. This course provides an understanding of the problems an engineer will face when designing a cyber-physical system: the selection of the controller s architecture, the interfacing with physical sensors and actuators, the modelling of the system and the interaction between its software and hardware components, as well as the analysis of its reachability and real-time performance. This course will emphasize on designing highly confident systems with real-time and concurrent behaviors. In particular, the following topics will be covered:
• Cyber-physical system introduction
• CPS applications and systems (e.g., smart refrigerators, elevator control, traffic control, automotive systems, smart grids, healthcare devices)
• Sensors and actuators for physical processes
• Computer hardware: programmable logic controllers (PLC), single-board computers (SBC), and field-programmable gate arrays (FPGA).
• System modeling, model-based design, and timed-automata

• Real-time scheduling with resource-constrained platforms
• Analysis of concurrent behavior
• Feedback control for computing systems
• Hybrid dynamics caused by the interaction between software and hardware components
• Networked system composition

Intended Learning Outcomes:
On successful completion of the course, students will be able to:
- explain the main concepts necessary to model, implement and analyze embedded systems
- describe the architecture of embedded controllers
- explain the interfacing between a controller and its physical environment (sensors and actuators) and its effects to the modeling of an embedded system
- explain the principles and models of concurrent computation
- calculate composition of state machines according to different kinds of composition
- explain characteristics of multitasking program and scheduling policies
- express and analyze simple specifications using temporal logic
- explain the different techniques used to perform reachability and real-time analyses
- model cyber-physical systems
- design, analyze, and control cyber-physical systems on a basic level

Teaching and Learning Methods:
Lectures and exercises

Media:
Slides of lectures, exercise sheets with assignments, collections of assignments, other working material.

Reading List:
Introduction to Embedded Systems, A Cyber-Physical Systems Approach. Edward A. Lee and Sanjit A. Seshia. http://LeeSeshia.org, ISBN 978-0-557-70857-4, 2011.
Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems. Peter Marwedel. ISBN 978-94-007-0256-1, 2nd ed. 2011
E. A. Lee and S. A. Seshia, Introduction to Embedded Systems - A Cyber-Physical Systems Approach, LeeSeshia.org, 2011.
P. Marwedel, Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems, Springer
A. J. Van Der Schaft, An Introduction to Hybrid Dynamical Systems, Springer
Introduction to Robotics Mechanics and Control John J, Craig, Prentice Hall. ISBN 0-13-123629-6

Responsible for Module:
Abdelhafez, Amr; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Embedded Systems, Cyper-Physical Systems and Robotics (INHN0018) (Vorlesung, 4 SWS)

Abdelhafez A, Hafez A, Mousa H, Xie P

Übung zu Embedded Systems, Cyper-Physical Systems and Robotics (INHN0018) (Übung, 2 SWS)
Abdelhafez A [L], Hafez A, Mousa H, Xie P
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0019: Business Process Management | Business Process Management

Version of module description: Gültig ab winterterm 2022/23

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 60	**Contact Hours:** 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination takes the form of a written test with the duration of 90 minutes. It is intended to demonstrate that the fundamentals and modeling methods of business process management have been understood and can be applied. This includes the implementation of selected scenarios in process models using the studied process modeling languages such as BPMN. Furthermore, the ability to transform process models into other languages like Petri nets will be demonstrated by example and presented process verification methods like reachability analysis will be applied. Furthermore, findings from the exercises can be reported and corresponding questions can be answered.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
None

Content:
• Basic terms of business process management
• Business process management in companies
• Modeling of business processes and data (BPMN, EPK, petri nets)
• Verification of selected properties with process models
• Basics of the development of process-oriented applications
• Use of process-oriented applications in practice
• Contribution of business process management to digital transformation
• Basics of process mining

Intended Learning Outcomes:
After participating in the module, students are able to understand terms and methods of business process management and classify the use of processes and process models with their respective benefits in different industries. They will also be able to create correct process models as a basis for designing information systems. They will be able to prove correctness of process models via accessibility analysis. Students understand how process models contribute to the development of process-oriented applications and are familiar with examples of process engines and process-aware information systems. Students recognize the importance of process-oriented applications based on real-world processes and can thus classify their contribution to business informatics and digital transformation in companies. Finally, students understand the basics of process mining for the analysis of processes and can apply selected process mining techniques.

Teaching and Learning Methods:
Lecture, tutorial, self-study assignments

Media:
Slides, videos, moodle, exercises

Reading List:
Weske, M. (2019) Business Process Management - Concepts, Languages, Architectures, Third Edition. Springer 2019, ISBN 978-3-662-59431-5, pp. 1-417 2019
Journal and conference articles for the individual topics will be announced separately.

Responsible for Module:
Pufahl, Luise; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Exercise Business Process Management (INHN0019) (Übung, 2 SWS)
Khraiwesh S (Pufahl L), Pufahl L

Business Process Management (INHN0019) (Vorlesung, 2 SWS)
Khraiwesh S, Pufahl L (Khraiwesh S)
For further information in this module, please click campus.tum.de or here.

Required Modules Mathematics | Pflichtmodule Mathematik

Module Description

INHN0004: Discrete Structures | Diskrete Strukturen

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 8	**Total Hours:** 240	**Self-study Hours:** 150	**Contact Hours:** 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students are assessed by means of a written 180 minutes exam consisting of a list of exercises. Some exercises test if the student can correctly use the mathematical vocabulary about sets, relations, logic, graphs and other mathematical objects introduced in the lectures. Further exercises test if the student is able to select the right logical, combinatorial, graph theoretical, or algebraic technique for the solution of a specific problem, and can apply it correctly.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
None

Content:
The lecture introduces elementary concepts and important areas of discrete mathematics that are relevant for informatics students. It covers the following five topics:
1) Basic concepts of sets, relations and functions:
- sets: basic operations, equivalence laws, KV-diagram, countable and uncountable sets, Cantor's Theorem
- relations: join, transitive hull, relational algebra
- functions: basic properties, composition, inverse
2) Fundamentals of Propositional Logic and First-Order Logic:
- Propositional Logic:
- syntax and semantics
- truth tables and their connection to KV-diagrams
- equivalence laws

- CNF, DNF, normalization procedure, equisatisfiability
- SAT-procedure: DPLL, resolution, proof of correctness
- modelling with propositional logic
- Predicate Logic:
- syntax and semantics
- equivalence laws
- modelling with predicate logic
3) Basics of combinatorics:
- counting principles
- drawing of balls from urns: variations, permutations, combinations
- binomial coefficients: symmetry, identities of Pascal and Vandermonde
- distribution problems
- Stirling-numbers of the first and second kind
- ordered and unordered partition functions
- application: load distribution
4) Basics of graph theory:
- basic definitions
- trees
- Euler and Hamilton circuits: Euler's theorem, theorems of Dirac and Ore
- planar graphs: Euler's polyhedron formula, Kuratowski's theorem
- matchings: marriage theorem, augmenting paths
- matchings with preferences: Gale-Shapley's theorem
5) Algebraic basics:
- basic definitions: algebra, group, ring, field
- groups:
- order: Lagrange's theorem, generator, group exponent
- cyclic groups
- basics of number theory: largest common divisor, extended euclidean
algorithm, Euler's phi function
- multiplicative groups of integers modulo n
- RSA

Intended Learning Outcomes:
On successful completion of the module, students will be able to
- understand the elementary vocabulary of discrete mathematics and use logic, algebraic und algorithmic calculi,
- solve combinatoric problems,
- model and solve problems using graph theory, and
- do a quantitive analysis of the efficiency of algorithms.

Teaching and Learning Methods:
The module consists of lectures and tutorials. During the lectures students are asked to solve small exercises online.
Students also receive weekly assignments, whose solution is discussed in the tutorials.

Media:
Slide show, blackboard, written assignments.

Reading List:
- A. Steger: Diskrete Strukturen, Band 1: Kombinatorik, Graphentheorie, Algebra, Springer, 2001
- K.H. Rosen: Discrete Mathematics And Its Applications, McGraw-Hill, 1995
M. Aigner: Diskrete Mathematik, Vieweg, 1999 (3rd Edition)
- R.L. Graham, D.E. Knuth, O. Patashnik: Concrete Mathematics: a Foundation for Computer Science, Addison-
Wesley, 1994
- D. Gries, F.B. Schneider: A Logical Approach to Discrete Math, Springer, 1993
- D.L. Kreher, D.R. Stinson: Combinatorial Algorithms: Generation, Enumeration, and Search, CRC Press, 1999
- S. Pemmaraju, S. Skiena: Computational Discrete Mathematics: Combinatorics and Graph Theory with
Mathematica, Cambridge University Press, 2003
- Schöning, Uwe: Logik für Informatiker, Spektrum-Verlag, 2000 (5. Auflage)

Responsible for Module:
Luttenberger, Michael; Prof. Dr. rer. nat. habil.

Courses (Type of course, Weekly hours per semester), Instructor:
Übungen zu Diskrete Strukturen (INHN0004) (Übung, 2 SWS)
Bohn J, Luttenberger M

Diskrete Strukturen (INHN0004) (Vorlesung, 4 SWS)
Luttenberger M [L], Bohn J, Luttenberger M
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0009: Computational Mathematics 1 - Linear Algebra | Computational Mathematics 1 - Lineare Algebra

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 8	**Total Hours:** 240	**Self-study Hours:** 150	**Contact Hours:** 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module examination is based on a written exam (90 minutes). Students have to show their knowledge of basic concepts of linear algebra and its applications. They have to discuss solutions for vector and matrix calculations in limited time.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0004 Discrete Structures

Content:
- Complex numbers
- Vector and matrix calculus
- Systems of linear equations
- Vector spaces
- Linear combinations and bases
- Dimension
- Linear maps and representation matrices
- Determinants
- Eigenvalues
- Scalar products
- Symmetric matrices

Intended Learning Outcomes:
After having attended this module, the students are familiar with the basic notions and methods of linear algebra. They are proficient in vector and matrix calculus as well as in the theory and

application of linear mappings including their representation by matrices, and they are aware of determinants and eigenvalues as an essential characteristics of matrices. The students can handle the objects of liner algebra in computational and algorithmic ways, and can apply this to problems in computer science.

Teaching and Learning Methods:
The module is offered as lectures with accompanying practice sessions. In the lectures, the contents will be presented in a talk with demonstrative examples, as well as through discussion with the students. The lectures should motivate the students to carry out their own analysis of the themes presented and to independently study the relevant literature. Corresponding to each lecture, practice sessions will be offered, in which exercise sheets and solutions will be available. In this way, students can deepen their understanding of the methods and concepts taught in the lectures and independently check their progress. At the beginning of the module, the practice sessions will be offered under guidance, but during the term the sessions will become more independent, and intensify learning individually as well as in small groups.

Media:
blackboard

Reading List:
A. Beutelspacher: Lineare Algebra, 6. Auflage, Vieweg+Teubner, 2006.

Responsible for Module:
Luttenberger, Michael; Prof. Dr. rer. nat. habil.

Courses (Type of course, Weekly hours per semester), Instructor:
Computational Mathematics 1 - Lineare Algebra (INHN0009) (Vorlesung, 4 SWS)
Anzt H

Übungen zu: Computational Mathematics 1 - Lineare Algebra (INHN0009) (Übung, 2 SWS)
Anzt H
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0013: Information Theory and Theoretical Informatics | Informationstheorie und theoretische Informatik

Version of module description: Gültig ab winterterm 2022/23

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 90 up to 150 minutes written test.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0004 Discrete Structures, INHN0009 Computational Mathematics 1: Linear Algebra

Content:
1. Models of computation, Church-Turing conjecture, Turing machines, string rewriting and formal grammars, determinism and nondeterminism
2. (Turing) computable functions, semidecidable/recognizable recursively enumerable languages, decision problem vs. computing, non-computable functions and the halting problem (Rice's theorem and Rice-Shapiro theorem)
3. Chomsky hierarchy, Kuroda and Chomsky normal forms for grammars and corresponding restrictions to Turing machines
4. Regular languages, finite automata (FA), regular grammars, regular expressions, standard constructions/translations/closure properties, DFA vs NFA, pumping lemma, Myhill-Nerode and minimization (application to synthesis and verification, PFA)
5. Context-free languages, context-free grammars, push-down automata (PDA), standard constructions/translations/closure properties and PCP, determinism vs. nondeterminism, pumping lemma, syntax trees and Cocke-Younger-Kasami algorithm (Dyck languages, Chomsky-Schützenberger)
6. Complexity theory: Turing machines with time/space bounds, deterministic vs nondeterministic polynomial time, NP-hard and NP-complete problems, Cook-Levin theorem and SAT, polynomial-time reductions, overview on important NP-hard and NP-complete problems.

7. Foundations of information theory: Huffman code, arithmetic codes, discrete probability spaces and Cox's postulates, optimal codes and Shannon entropy and information, compression by means of factoring (Lempel-Ziv), Kolmogorov complexity
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Formal languages, grammars, Chomsky hierarchy.
Regular languages: DFA, NFA with and without ε-transitions, regular expressions and translations between them;
systems of language equations; closure under boolean operations;
Arden's lemma; pumping lemma; decision problems; minimization;
Myhill-Nerode theorem.
CFLs: PDAs and translation between CFGs and PDAs; proof that DPDAs are weaker than PDAs; closure properties;
CYK algorithm; pumping lemma; Chomsky and Greibach normal forms.
Context-sensitive languages and LBAs.
Computability: computability, decidability, semi-decidability, recursive-enumerability and their relationships; existence of non-computable problems; Turing machines, accepted languages, type-0 languages: equivalence of Turig machines, While programs and Goto-programs; primitive and μ-recursive functions; reductions between problems;
the Halting problem; universal Turing machines; Rice's theorem; Rice-Shapiro theorem; undecidability of the Post Correspondence Problem and important problems on CFGs.
Complexity theory: time and space complexity classes; polynomial-time reductions; the classes P and NP; NP completeness;
Cook's theorem; important NP-complete problems and reductions between them.
Foundations of information theory

Intended Learning Outcomes:
After successfully completing this module, the students understand the
core concepts of the theory of computation on a basic but scientific
level. They know what regular expressions, context-free grammars, the
Chomsky hierarchy, finite automata and Turing machines are. They can define formal languages with the appropriate grammars or machines. They can prove that a given language cannot be defined with a given class of grammars or machines. They can prove that certain grammars and machines are equivalent and they can transform them into each other algorithmically. They can explain the basic concepts of complexity theory and information theory and can reduce decision problems algorithmically to each other under given complexity limitations.

Teaching and Learning Methods:
The module consists of lectures and tutorials. In the lectures, the material is presented by the teacher, in dialogue with the students.
During the tutorials, the students work on given exercises either individually or in small groups with help from the tutors. Exercises and homework are primarily pen and paper based but can also involve computerbased components.

Media:
Lecture notes, slides, blackboard, animations, video recordings, online exercises and homework assignments, online discussion forum

Reading List:
John E. Hopcroft, Rajeev Motwani, Jeffrey D. Ullman. Introduction to Automata Theory, Languages, and Computation Dexter Kozen. Automata and Computability
Katrin Erk, Lutz Priese. Theoretische Informatik. Eine umfassende Einführung.
Uwe Schöning. Theoretische Informatik kurzgefasst.
T.M. Cover and J.A. Thomas: Elements of Information Theory.
D.J.C. MacKay: Information Theory, Inference, and Learning Algorithms.

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Übungen zu Informationstheorie und theoretische Informatik (INHN0013) Campus Heilbronn (Übung, 2 SWS)
Kobourov S

Informationstheorie und theoretische Informatik (INHN0013) Campus Heilbronn (Vorlesung, 3 SWS)
Kobourov S [L], Kobourov S, Miller J, Zink J
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0014: Computational Mathematics 2 – Calculus | Computational Mathematics 2 - Analysis

Version of module description: Gültig ab winterterm 2024/25

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 8	**Total Hours:** 240	**Self-study Hours:** 150	**Contact Hours:** 90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination takes the form of a 120-minute written exam. This exam assesses the extent to which students understand the elementary methods of real analysis and the concepts of convergence and approximation and are able to work out solutions to application problems in differential and integral calculus as well as simple differential equations appropriately, even under time pressure.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Discrete Structures, Computational Mathematics 1

Content:
Basics on real numbers:
Ordering of the real numbers
Infimum, supremum
Rational numbers are dense in the reals
Triangle inequality, Cauchy Schwarz inequality
Sequences:
Convergence in C and R
Improper convergence (convergence to plus/minus infinity)
Properties of limits
asymptotic equality of sequences
monotone sequences
Series:
Convergence and absolute convergence of series

Important examples: harmonic series, geometric series, exponential series, alternating series
Criteria for convergence (among others comparison test, ratio test)
Rearrangement, Cauchy product
Continuity:
Intermediate value theorem
Minima and maxima of continuous functions
Compact sets
Inverse functions
Important classes of functions:
Polynomials
Rational functions
Exponential function and logarithm
Trigonometric functions
Differentiability of functions of a single variable:
Landau symbols
Differentiation rules (product rule, quotient rule, chain rule, derivative of the inverse function)
Mean value theorem
Higher derivatives
Taylor formula
Power series
L'Hospital's rule
Curve sketching
Integration in one variable:
Fundamental theorem of calculus
Antiderivative
Integration by parts, substitution rule
Improper integrals
Integrals depending on a parameter
Differential calculus of functions of several variables:
partial derivatives, gradient, Jacobi and Hesse matrix
Necessary and sufficient criteria for local extrema
Plane curves
Elementary introduction to differential equations:
Classification, examples
Initial value problems for separable equations
Linear differential equations

Intended Learning Outcomes:
Having attended this module, the students are able to understand the elementary notions and methods of real analysis as well as of convergence and approximation. They are moreover able to apply the methods of differential calculus of functions of a single and of several variables, as well

as of integral calculus of a function of a single variable, and they understand important function classes and simple examples of differential equations.

Teaching and Learning Methods:
The module is offered as lectures with accompanying practice sessions. In the lectures, the contents will be presented in a talk with demonstrative examples, as well as through discussion with the students. The lectures should motivate the students to carry out their own analysis of the themes presented and to independently study the relevant literature. Corresponding to each lecture, practice sessions will be offered, in which exercise sheets and solutions will be available. In this way, students can deepen their understanding of the methods and concepts taught in the lectures and independently check their progress. At the beginning of the module, the practice sessions will be offered under guidance, but during the term the sessions will become more independent, and intensify learning individually as well as in small groups.

Media:
Blackboard

Reading List:
1) F. Bornemann: Konkrete Analysis, Springer-Verlag 2008.
2) M. Oberguggenberger, A. Ostermann: Analysis für Informatiker, 2. Auflage, Springer-Verlag 2009.

Responsible for Module:
Anzt, Hartwig; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Computational Mathematics 2 - Analysis (INHN0014) Campus Heilbronn (Vorlesung, 4 SWS)
Anzt H [L], Anzt H

Übungen zu Computational Mathematics 2 - Analysis (INHN0014) Campus Heilbronn (Übung, 2 SWS)
Anzt H [L], Anzt H, Göbel F
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0020: Discrete Probability Theory | Diskrete Wahrscheinlichkeitstheorie

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students will be assessed by a 120 minutes written exam, which consists of three types of exercises. Comprehension exercises test if the student understands the basic concepts and theorems of the lecture. They require students to apply these concepts to examples. Algorithmic exercises test if the student knows and is able to apply the presented rules to selected inputs. Modelling exercises test the ability of the student to use the mathematical tools from the lectures to model and solve concrete problems.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0004 Discrete Structures, INHN0009 Computational Mathematics 1: Linear Algebra, INHN0014 Computational Mathematics 2: Calculus

Content:
-Fundamentals of (discrete) probability theory
++ probability spaces, events, principle of inclusion/exclusion, Boolean inequality, conditional probability, multiplication
theorem, total probability theorem, Bayesian theorem, independence
++ random variables, expected value, variance, linearity of expected value, conditional random variables and their
expected value, variance, moments and central moments, several random variables and their common density &
distribution, independence from random variables, moments of composite random variables, indicator variables

++ discrete distributions: Bernoulli distribution, binomial distribution, geometric distribution, coupon collector problem,
Poisson distribution, relationships among distributions
++ methods for estimating probabilities, inequalities of Markov and Chebyshev, Chernoff barriers
++ Law of large numbers
++ Probability-generating functions and their application to distributions, moment-generating functions with various
applications
-continuous probability spaces
++ continuous random variables, Kolmogorov axioms, sigma algebras, Lebesgue integrals, computing with
continuous random variables, simulation of random variables
++ continuous distributions: Equal distribution, normal distribution and linear transformation, exponential distribution
and waiting processes, relationship with discrete distributions
++ several continuous random variables, boundary distributions and independence, sums of random variables
++ Moment generating functions for continuous random variables
++ Central limit theorem
-Inductive Statistics
++ estimation variables, maximum likelihood principle, confidence intervals, hypothesis testing, statistical test
development and application
-Stochastic processes
++ processes with discrete time, Markov chains, transition probabilities, arrival probabilities, transition times, return
times, fundamental theorem for ergodic Markov chains

Intended Learning Outcomes:
After successful completion of the module
- Participants are familiar with important concepts of discrete and continuous probability spaces and stochastic processes and can in large part deduce them themselves
- master calculation rules for the determination and estimation of probabilities, expected values and variances,
- are able to map real problems to abstract probability spaces and
- can easily apply simple statistical tests.

Teaching and Learning Methods:
The module consists of lectures and tutorials. During the lectures students are asked to solve small exercises online.
Students also receive weekly assignments, whose solution is discussed in the tutorials.

Media:
Slide show, blackboard, written assignments.

Reading List:
- T. Schickinger, A. Steger: Diskrete Strukturen - Band 2, Springer Verlag, 2001
- Nobert Henze: Stochastik für Einsteiger, Vieweg, 2004
- R. Mathar, D. Pfeifer: Stochastik für Informatiker, B.G. Teubner Stuttgart, 1990
- M. Greiner, G. Tinhofer: Stochastik für Studienanfänger der Informatik, Carl Hanser Verlag, 1996
- H. Gordon: Discrete Probability, Springer-Verlag, 1997
- R. Motwani, P. Raghavan: Randomized Algorithms, Cambridge University Press, 1995
- L. Fahrmeir, R. Künstler, I. Pigeot, G. Tutz: Statistik - Der Weg zur Datenanalyse, Springer-Verlag, 1997

Responsible for Module:
Fraser, Alexander; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Exercise Discrete Probability Theory (INHN0020) (Übung, 2 SWS)
Fraser A [L], Fraser A, Hoock B, Okabe S

Discrete Probability Theory (INHN0020) (Vorlesung, 3 SWS)
Fraser A [L], Fraser A, Okabe S
For further information in this module, please click campus.tum.de or here.

Elective Modules Information Systems | Wahlmodule Informatik

Module Description

CITHN10001: Introduction to Hardware Design Languages and Tools | Introduction to Hardware Design Languages and Tools

Version of module description: Gültig ab winterterm 2024/25

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
1. In-class performance (1 quiz per Lab): Evaluation of student's performance during the lab sessions, including the take-away messages about the digital circuit fundamentals and understanding of implementing basic circuits, and effective use of Verilog HDL. The students get bonus points added to their final grade.
(Max.: 10 points. 2 points/quiz for 5 quizzes. Top 1/2/3: 2/1.5/11, others 0.5)
2. Regular exercise (Artemis/TBD): Small design tasks to assess students' ability to design and simulate their entities accurately using Verilog simulators and verify the functionality against expected outputs. Students will be evaluated based on their understanding of the simulation results and ability to identify and rectify errors.
(Max.: 35 points. 7 points/exercise for 5 exercises. hard exercises)
3. Bonus exercise: Hard exercises about specific tasks, depending on the covered topics.
(Max.: 10 points. 5 points/exercise for 2 exercises)
4. Mini report/presentation/defense: Assessment of students' documentation and reporting skills through lab reports. Reports/presentations should demonstrate their understanding of the design process, Verilog code, simulation results, and design iterations or modifications. A brief defense is required: the students must answer some questions about their design work. Report: 3-5 IEEE pages. Presentation: 5 slides (10 min). Defense: 3-5 questions (5 min)
(Max.: 55 points. 30 points for the report, 20 points for the presentation, and 5 points for the defense

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Basic knowledge of computer architecture and programming,
INHN0006 Introduction to Software Engineering, INHN0007 Operating Systems and System Software

Content:
1. Develop a fundamental understanding of digital circuits.
2. Gain hands-on experience in designing and implementing basic digital circuits using Verilog HDL.
3. Acquire proficiency in simulating and verifying digital designs using Verilog simulators.
4. Develop problem-solving skills through the analysis and debugging of circuit designs.
5. Familiarize students with the design process and workflow used in hardware design.

Intended Learning Outcomes:
The supervising chair offers this module. The topics are selected based on their research and education preferences related to computer architecture and operating systems.
1. An overview of digital circuits and hardware design language - Verilog HDL, including syntax, modules, data types, operators, and control structures.
2. Introduction to combinational/sequential logic design, including flip-flops, registers, counters, procedural blocks, and state machines.
3. Introduction to the concept of test-benches for functional verification.
4. Hand-on skills in hardware design, simulation, and verification with industrial tools.

Teaching and Learning Methods:
Students are expected to learn basic concepts about implementing primary combinational/ sequential logic circuits and explore behavioral modeling and simulation processes. Participants practice design work through elementary exercises and project work in small groups. The results of teamwork are required in the form of reports and presentations. A defense session is necessary to evaluate the performance of the student’s work.

Media:
Beamer, slides, whiteboard, BBB, Gitlab, Artemis, development environment

Reading List:
- Verilog HDL: A Guide to Digital Design and Synthesis, Samir Palnitkar
- Digital Design with RTL Design, VHDL, and Verilog, Frank Vahid and Roman Lysecky
- Verilog by Example: A Concise Introduction for FPGA Design, Volnei A. Pedroni
- Digital Logic Design Using Verilog (Coding and RTL Synthesis), Vaibbhav Taraate
- Vivado Design Suite User Guide: Getting Started (UG910)
- Yosys Open SYnthesis Suite, Claire Wolf
- Yosys+nextpnr: Open Source Framework from Verilog to Bitstream for Commercial FPGAs, David Shah, Eddie Hung, Clifford Wolf, Serge Bazanski, Dan Gisselquist, Miodrag Milanović.

Responsible for Module:
Trinitis, Carsten; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Introduction to Hardware Design Languages and Tools CITHN10001 (Vorlesung, 5 SWS)
Trinitis C
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN1002: Tools and Practice in Digital Research and Engineering | Tools and Practice in Digital Research and Engineering

Block Course, the week before lecture starts

Version of module description: Gültig ab winterterm 2024/25

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 1	**Total Hours:** 30	**Self-study Hours:** 15	**Contact Hours:** 15

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Written exam, 60 minutes, the examination will probe the students‘ understanding of the principles and best practices in digital research. They are allowed to bring a cheat sheet, double-sided, with hand-written notes on how to use the tools and apply the principles taught in the lecture.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
None

Content:
The students learn good practice and tools in digital research and engineering. On the first day, the students are exposed to linux shell usage and learn a set of central commands. In hand on exercises they experience the functionality of a shell. The second day introduces the basics of ssh for remote access and the use of ssh keys for authentication. In hands-on sessions, the students apply these concepts, generate their own ssh keys, and learn how to access remote servers. On the third day, the students learn the concepts of repositories for collaborative development and gain hands-on experience in setting up and collaborating on git repositories. On the fourth day, the students get introduced to continuous integration and unit testing on git platforms (github or gitlab) and gain experience in setting this up for their own projects. The last day covers latex document development including the use of sharelatex and overleaf.

Intended Learning Outcomes:
The students know key commands for linux shell usage and how to generate, deploy, and use ssh keys. The students understand the concepts behind versioning systems, continuous integration,

and unit testing. They have gained expertise in applying the concepts themselves and create git repositories for collaboration, continuous integration pipelines, and how to use unit test frameworks. The students also know how to use latex for document processing.

Teaching and Learning Methods:
The block course consists of 6h per day for 5 days, each day is split into a morning session (3h) where the material is presented with slides and hands-on exercise. Interactive session. The afternoon is reserved for self-study and preparation for the exam (3h).

Media:
Presentation, Hands-On Exercises, Self-Study Exercises

Reading List:
A short introduction to Latex, Aibara, 2019.

Responsible for Module:
Anzt, Hartwig; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Block-Course Tools and Practice in Digital Research and Engineering (CITHN1002) (Vorlesung, 1 SWS)
Anzt H [L], Anzt H

Block-Course Tools and Practice in Digital Research and Engineering (CITHN1002) (Vorlesung, 2 SWS)
Anzt H [L], Anzt H
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN1004: Algorithms for Graph Drawing | Algorithms for Graph Drawing

Version of module description: Gültig ab summerterm 2025

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 90 minutes written examination. In the written exam, based on the given questions, the students are expected to demonstrate understanding of the conceptual and mathematical basics of algorithm analysis and efficient data structures in a geometry context. Students must recognize and analyze typical algorithmic problems and be able to find efficient solutions within a limited scope of time. There will be approximately one voluntary homework per week, which shall take about 60–120 minutes to solve. The lecturer can offer that the homework solutions produced by the students are corrected such that the students receive individual feedback.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Discrete Structures
Foundations of Algorithms and Data Structures
Information Theory and Theoretical Informatics

Content:
This course covers the most important algorithms for drawing graphs. We will use methods from algorithmic graph theory and algorithmics such as divide and conquer, flow networks and integer programming. We will get to know measures for the quality of a graph drawing and algorithms that optimize these measures. Methods for drawing trees, planar graphs on grids, orthogonal visualizations and directed graphs will be presented and analyzed.

Intended Learning Outcomes:
Students are given an overview of the topic of graph drawing and learn about typical tools used therein. They know algorithms for the geometric representation of graphs and can apply them. In addition, students will be able to develop their own approaches to solving graph drawing problems and prove their correctness. They also deepen their knowledge of modeling and solving problems using graphs and graph algorithms.

Teaching and Learning Methods:
The module consists of lectures and tutorials. The content of the lectures is conveyed by presentations of the scientific material. By solving homework assignments, the students are encouraged to work on topics that build on each other. This will help to understand, apply and adapt the methods learned in the lectures. Solutions of the homework assignments are discussed in the tutorials.

Media:
Slides, whiteboard, homework assignments

Reading List:
Giuseppe Di Battista, Peter Eades, Roberto Tamassia, Ioannis G. Tollis: Graph Drawing: Algorithms for the Visualization of Graphs. 1st Edition, Pearson, 1998.

Michael Kaufmann, Dorothea Wagner: Drawing Graphs: Methods and Models. 1st Edition, Springer, 2001.

Takao Nishizeki, Md. Saidur Rahman: Planar Graph Drawing. 1st Edition, World Scientific, 2004.

Roberto Tamassia: Handbook of Graph Drawing and Visualization. 1st Edition, CRC Press, 2013.

Responsible for Module:
Kobourov, Stephen; Prof. Ph.D.

Courses (Type of course, Weekly hours per semester), Instructor:
Algorithms for Graph Drawing (CITHN1004) (Vorlesung mit integrierten Übungen, 5 SWS)
Förster H, Kobourov S
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN1005: Introduction to Data Visualization | Introduction to Data Visualization [Introduction to Data Visualization]

Version of module description: Gültig ab summerterm 2025

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 120 minutes written test. In the written exam, based on the given questions, the students are expected to demonstrate understanding of algorithms and techniques for data visualization.

There will be approximately one voluntary homework per week.
The docent can offer that the voluntary homework solutions produced by the students are corrected such that the students receive individual feedback. If the homework is corrected and the points achieved in the homework lie above 70% of the total points threshold, the docent can grant a bonus of 0.3 to the grade in the final exam. This bonus does not carry over to later years and it can only be applied if the student passes the exam (even without the bonus). The solutions of the homework assignments are discussed in the tutorials.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Foundations of Algorithms and Data Structures

Content:
Data visualization is a research area that focuses on visualization techniques and algorithms to help people understand and analyze data. Visualization allows us to visually perceive relationships, patterns, and trends. While statistical techniques may determine correlations among the data, visualization helps us frame what questions to ask. One challenge lies in developing algorithmically efficient methods to visualize large and complex data sets. Another challenge is to develop effective visualizations that make the underlying patterns and trends easy to see. Even tougher

is the challenge of providing interactive access, analysis, and filtering. Topics include: algorithms, data structures and engineering techniques for implementing and managing data visualizations; perception, design and evaluation; high-dimensional data visualization, network visualization, text visualization.

Intended Learning Outcomes:
After completion of the module, students are able to understand the theoretical principles behind data visualization. This includes knowledge about domain abstraction, visual encoding and interactivity, as well as visualization algorithms for fundamental problems such as dimensionality reduction, graph and hypergraph embeddings, as well as techniques for tabular and geographic visualization. Students are able to apply the principles of visual perception, and perform quantitative and qualitative evaluations. They are able to create their own interactive data visualizations of large data sets.

Teaching and Learning Methods:
The module consists of lectures and tutorials. The content of the lectures is conveyed by presentations of the scientific material. By solving voluntary homework assignments, the students are encouraged to work on topics that build on each other. The homework assignments are graded so that students receive individual feedback and the solutions of the assignments are discussed in the tutorials.

Media:
Slides, whiteboard, homework assignments.

Reading List:
Tamara Munzner, Visualization Analysis and Design, A K Peters/CRC Press, 1st Edition, 2014.

Responsible for Module:
Kobourov, Stephen; Prof. Ph.D.

Courses (Type of course, Weekly hours per semester), Instructor:
Introduction to Data Visualization (CITHN1005) (Vorlesung mit integrierten Übungen, 4 SWS)
Kobourov S [L], Wallinger M
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN1006: Efficient Algorithms | Efficient Algorithms

Version of module description: Gültig ab summerterm 2025

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 120 minutes written test. In the written exam, based on the given questions, the students are expected to demonstrate understanding of the conceptual and mathematical basics of algorithm analysis, as well as advanced knowledge in the area of efficient data structures and algorithms. Students must recognize and analyze typical algorithmic problems and be able to find efficient solutions within a limited scope of time.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0004 Discrete Structures
INHN0008 Foundations of Algorithms and Data Structures
INHN0013 Information Theory and Theoretical Informatics

Content:
The module begins with a brief review of basic analysis techniques and then focuses on problems that are efficiently solvable. The main topics include algorithm design and analysis techniques, advanced data structures, graph algorithms and algorithms for further selected problems. The module concludes with basic techniques to show and deal with intractability.

Intended Learning Outcomes:
After completing the module, the students can analyze and assess the runtime and the memory requirements of efficient algorithms. Furthermore, they have a good understanding of numerous fundamental algorithms and data structures. This understanding enables them to design algorithms and data structures for new algorithmic problems.

Teaching and Learning Methods:
The module consists of lectures and exercise sessions. The content of the lectures is conveyed by presentations of the scientific material. By solving homework assignments, the students are encouraged to work on topics that build on each other. The homework assignments are graded so that students receive individual feedback and the solutions of the assignments are discussed in the exercise sessions.

Media:
Slides, whiteboard, homework assignments

Reading List:
• Thomas H. Cormen, Charles E. Leiserson, Ron L. Rivest, Clifford Stein: Introduction to Algorithms. 4th Edition, MIT Press, 2022.
• Thomas H. Cormen, Charles E. Leiserson, Ron L. Rivest, Clifford Stein: Introduction to Algorithms. 3rd Edition, MIT Press, 2009.
• Alan Gibbons: Algorithmic Graph Theory. Reprint 1st Edition, Cambridge Univ. Press, 1994
• Sven O. Krumke, Hartmut Noltemeier: Graphentheoretische Konzepte und Algorithmen. 3rd Edition, Springer Vieweg, 2012.

Responsible for Module:
Kobourov, Stephen, Prof. Dr: stephen.kobourov@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CITHN1007: Data Science | Data Science

Version of module description: Gültig ab winterterm 2025/26

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exam takes the form of a 120 minute written test. In the written exam, based on the given questions, the students are expected to demonstrate understanding of data science and techniques for data analysis.
The docent can offer that the homework solutions produced by the students are corrected such that the students receive individual feedback. If the homework is corrected and the points achieved in the homework lie above a predefined threshold, the docent can grant a bonus of 0.3 to the grade in the final exam. This bonus does not carry over to later years and it can only be applied if the student passes the exam (even without the bonus). The solutions of the homework assignments are discussed in the exercises sessions.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0008 Foundations of Algorithms and Data Structures
INHN0009 Computational Mathematics I: Linear Algebra
INHN0014 Computational Mathematics II: Calculus

Content:
As larger and more complex data continues to become widely available, it is increasingly important for practitioners to understand the fundamentals of data science. The field of data science covers a large breadth of topics relating to data: from acquiring data, to processing it, to analyzing it, to visualizing it, to communicating it. A key application of data science is that by applying rigorous mathematical methods to real-world observed phenomena, we can make better decisions, predict outcomes, and improve efficiency. We will cover the following topics:
- Introduction to Data Science: Defining data, data science, and key terminology. Understanding the role of data in decision-making and the data analysis pipeline.

- Data Types and Structures: Identifying numerical, ordinal, categorical, textual, and relational data, along with best practices for data cleaning, representation, and encoding. Using Python, Jupyter notebooks, and common libraries.
- Statistical Analysis and Testing: Scalar numerical analysis, A/B testing, hypothesis testing (parametric, non-parametric, bootstrap), and linear regression.
- Multivariate Analysis: Techniques for dimensionality reduction (linear and non-linear). Clustering algorithms and classification methods may also be studied.
- Relational Data Analysis: Understanding graph structures, layout algorithms, and centrality measures.
- Block models, diffusion processes, clustering, and anomaly detection may also be studied.
- Machine Learning for Data Science: Neural networks for regression and classification. Graph neural networks may also be studied.
- Interpreting Results: Techniques for understanding correlations, probabilities, and confidence intervals, and the significance of findings.
- Visual Analytics: Principles of effective data visualization, interactivity, and data communication.
- Ethical Considerations: Awareness of common data science pitfalls, including p-hacking, data privacy, and the ethical implications of data-driven decisions.

Intended Learning Outcomes:
After completion of the module, students are able to understand and apply the key principles of data science. This includes identifying and acquiring raw data, cleaning data, and identifying appropriate analysis techniques. Students are able to understand and apply state-of-the-art techniques for statistical, multivariate, and network analysis with both classical and machine learning based approaches. They are able to effectively communicate findings through simple visualizations, and be aware of potential ethical considerations when communicating analysis results.

Teaching and Learning Methods:
The module consists of lectures and exercise sessions. The content of the lectures is conveyed by presentations of the scientific material. By solving homework assignments, the students are encouraged to work on topics that build on each other. The homework assignments are graded so that students receive individual feedback and the solutions of the assignments are discussed in the exercise sessions.

Media:
Slides, whiteboard, homework assignments.

Reading List:
Gareth James, Daniela Witten, Trevor Hastie, Rob Tibshirani, Jonathan Taylor. An Introduction to Statistical Learning with Applications in Python. Springer Texts in Statistics, 1st edition, 2023

Ulrick Brandes, Thomas Erlebach. Network Analysis: Methodological Foundations. Springer Lecture Notes in Computer Science, 1st edition, 2005

Responsible for Module:
Kobourov, Stephen; Prof. Ph.D.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CITHN2012: Introduction to C++ | Introduction to C++

Version of module description: Gültig ab summerterm 2025

Module Level: Bachelor/Master	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination is realized with an individual software project, an accompanying report (6-8 pages), and a short presentation (10 Minutes). The project requires applying the programming concepts covered in class (i.e., fundamental language constructs and semantics, C++ classes, templating) and the development of a software library fulfilling a pre-defined purpose. The final grade composes of 60% software 30% report, 10% short presentation.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
INHN0002 Fundamentals of Programming
INHN0008 Fundamentals of Algorithms and Data Structures

Content:
• Fundamental language constructs
• Value and reference semantics
• Classes, member functions, operators and inheritance
• Standard library: containers, iterators, algorithms
• (Smart) Pointers, RAII, memory management and move semantics
• Organizing larger projects
• IDEs, compilation, build systems and debugging
• Templates, metaprogramming, SFINAE and concepts
• Multithreading, memory ordering, concurrency
• Basics of lock-free programming
• Parallel programming frameworks: OpenMP, TBB
• Tooling: Formatting, Linting, Static Analysis, Sanitizers,
• Libraries: IO, Testing, Benchmarking

Intended Learning Outcomes:
Students are able to
• Understand existing C++ code
• Recall the semantics of common components of the C++ language
• Implement small applications and libraries in modern C++
• Choose and combine appropriate algorithms and data structures from the C++ standard library
• Create file and class structures for larger-scale C++ projects
• Use appropriate tools to discover and fix bugs in their code
• Evaluate the performance of C++ code on a small scale

Teaching and Learning Methods:
The module consists of a lecture with accompanying exercise session, and exercise sheets. The lecture focuses on presenting the theoretical concepts, the exercise sheets recall the theoretical content. The exercise sessions bring the theoretical knowledge to action: the participants will need to apply the theoretical knowledge in the development of C++ software

Media:
Slides

Reading List:

Responsible for Module:
Anzt, Hartwig; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Introduction to C++ (CITHN2012) (Vorlesung, 4 SWS)
Anzt H

Übungen zu: Introduction to C++ (CITHN2012) (Übung, 2 SWS)
Anzt H
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN2014: Foundations and Application of Generative AI | Foundations and Application of Generative AI

Version of module description: Gültig ab winterterm 2025/26

Module Level: Bachelor/Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 105	**Contact Hours:** 75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The evaluation is based on a combination of preparatory assignments completed during exercise sessions (15%), the project implementation and report (60%), and a group presentation (25%).

Skills to be tested:
- Assignment: theoretical thinking, and hands-on capability using LLM
- Implementation: team-working, problem solving, integration of knowledge, project management
- Presentation: summarization, communication and collaboration

The assignments are completed individually and each student contributes 3-4 pages to the final group report and 2-3 minutes to the final group presentation.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Master: no prerequisite
Bachelor: INHN0001 Introduction to Informatics
INHN0002 Fundamentals of Programming

Content:
Basic principles of generative AI:
- Transformer architecture
- Training and inference of generative AI
- Large language model
- Stable diffusion

Prompt engineering:

- In-context learning
- Chain of thoughts
- Other advanced techniques like role-playing…
Applications of generative AI:
- LLM use cases and tasks
- GPT API call and plugin development
Open-source generative AI:
- Open-source models e.g., Llama 7B
- Loading & running
- Instruction tuning + fine tuning
Risk and security of generative AI:
- Limitations of generative AI
- Ethics issues
- Attack and defence of Generative AI (e.g., Jailbreak)

Intended Learning Outcomes:
Upon completion of the module, students are able to
- Understand generative AI deeply, including its historical development
- Comprehend and implement prompt engineering to enhance productivity
- Apply generative AI into different areas
- Navigate the ethical, compliance, and risk aspects associated with Generative AI

Teaching and Learning Methods:
The lecture is supplemented by integrated exercises, demonstrations and practical components. The exercises serve to consolidate the theoretical content and should be solved in small groups. Occasionally, individual exercises can also be set as voluntary homework. Students should be encouraged to repeat and experiment independently. The evaluation of your learning will be based on project report and the final presentation.

Media:
Slides, exercise sheets, board etc.

Reading List:
- Generative AI: Perspectives from Stanford HAI:
https://hai.stanford.edu/sites/default/files/2023-03/Generative_AI_HAI_Perspectives
- Generative AI at Work:
https://www.nber.org/system/files/working_papers/w31161/w31161.pdf
- Proactive Risk Management in Generative AI:
https://www2.deloitte.com/us/en/pages/consulting/articles/responsible-use-of-generati ve-ai.html
- Attention is All You Need:
https://research.google/pubs/pub46201/

Responsible for Module:
Chen, Chunyang, Prof: chun-yang.chen@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:
Übungen zu: Foundations and Application of Generative AI (CITHN2014) (Übung, 2 SWS)
Chen C

Foundations and Application of Generative AI (CITHN2014) (Vorlesung, 3 SWS)
Chen C
For further information in this module, please click campus.tum.de or here.

Elective Modules Economics | Wahlmodule Wirtschaftswissenschaften

Module Description

MGTHN0057: Seminar Operations & Technology Management: Business Analytics and its Application | Seminar Operations & Technology Management: Business Analytics and its Application

Version of module description: Gültig ab winterterm 2025/26

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 135	**Contact Hours:** 45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination consists of two parts: 1. The presentation (25% of the overall grade) by which it is proved that the students: have a solid overview over business and data analytics, and have modelling and data analytics skills in solving practical problems. 2. The research report (75% of the overall grade) by which it is proved that the students: understand the literature on a subtopic in the field of business analytics with applications, have learned the most important research methods in business analytics, are able to detect promising research questions and finding innovative ways to investigate them using data. The overall grade is calculated by averageing written work (75%) and presentation (25%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Foundations in statistics and management science

Content:
In this seminar, we will discuss how to use big data to solve business problems, and have a good understanding of business analytics. The seminar generally has four parts. Part 1: Review the literture on business analytics, review the literature on data analytics. Part 2: Examine and identify various public databases, for example, open source data (google mobility data), data from organizations such as WHO. Part 3: Propose a research question, build the correct model and find the approporiate dataset to support the analysis. Part 4. Present research ideas and write

an academic report. Thus, this course will be especially valuable to inspire research ideas and prepare for scientific work on the subsequent bachelor thesis or master study.

Intended Learning Outcomes:
Students who have participated in this seminar: have a comprehensive understanding of the scientific process; know about the most important issues of current business and management research; have a solid overview over diverse and innovative ways of collecting data and analyzing data; be able to think critically; solve business problems efficiently and innovatively using big data.

Teaching and Learning Methods:
Presentation, interactive teaching, e-learning, group discussions

Media:
Zoom, literature databases (Ebsco, ScienceDirect etc.), Databases, software development platform (e.g. GitHub)

Reading List:
Top 24 leading business journals - see https://jindal.utdallas.edu/the-utd-top-100-business-school-research-rankings/. In particular, we focus on the following five journals: Management Science, Operations Research, Journal of Operations Management, Manufacturing and Service Operations Management, Production and Operations Management. For example: Liu, J., Xie, J., Yang, K.K. and Zheng, Z., 2019. Effects of rescheduling on patient no-show behavior in outpatient clinics. Manufacturing & Service Operations Management, 21(4), pp.780-797. Xie, J., Zhuang, W., Ang, M., Chou, M.C., Luo, L. and Yao, D.D., Analytics for Hospital Resource Planning—Two Case Studies. Production and Operations Management.

Responsible for Module:
Xie, Jingui; Ph.D.

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar Operations & Supply Chain Management: Business Analytics and its Application (BMT Heilbronn) (MGTHN0057) (Seminar, 4 SWS)
Xie J, Yang N
For further information in this module, please click campus.tum.de or here.

Module Description

MGTHN0131: Accounting | Accounting

Version of module description: Gültig ab summerterm 2023

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Grading based on a written examination of 90 minutes (100%). In the examination, participants have to demonstrate their theoretical, conceptual, and practical competences related to both managerial decision-making and communication of corpo-rate data to stakeholders outside the company. Therefore, participants have to prove that they have gained the competences stated below (see intended learning outcomes of the module) by successfully working on separate assignments in the fields of generating/collecting, aggregating/processing, and using/reporting corporate date. Moreover, participants have to demonstrate that they can interpret and critically evaluate the accounting outcomes from a business, ethical, and societal perspective. In the examination, participants are allowed to use a non-programmable calculator. The final grade can be enhanced by one third of a grade through successful mid-term assignments.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
The module introduces to the essential techniques and requirements how companies generate/ collect, aggregate/process, and use/report corporate data for both managerial decision-making and stakeholders outside the company. The module captures established accounting techniques, legal requirements, managerial incentives, ethical considerations of accounting practices, and contemporary developments in the context of the digital transformation. The module captures the following topics:
• Corporate data and digital accounting tools
• Recording of business transactions and bookkeeping
• Cost accounting and performance analysis

• Financial reporting in line with the International Financial Reporting Standards (IFRS)
• Sustainability reporting
• Tax accounting
• Accounting incentives, accounting policies, and reporting analysis

Intended Learning Outcomes:
After successfully completing the module, participants have gained the competence to:
• systematically record business transactions,
• classify, distribute, and assign costs for operating performance analysis,
• produce and analyze financial reports in line with a major financial reporting system,
• produce and analyze sustainability reports and/or reports for tax authorities, and to
• critically discuss incentives and ethics of accounting choices.

Teaching and Learning Methods:
The module consists of a lecture with integrated exercise. In the lecture, the methods, regulations, practices, and ethics of accounting are presented and discussed with the participants. The lecture introduces to both the theoretical fundament and real-life practices of accounting and reporting. In the exercise, the content is trained with practical examples through exercise sheets and case studies.

Media:
Lecture slides, exercises, reporting standards, datasets, and financial reports available in TUM Moodle

Reading List:
• Alexander and Nobes. 2020. Financial accounting: An international introduction
• Korkmaz. 2022. Financial reporting with SAP S/4HANA
• Weetman. 2019. Financial and management accounting

Responsible for Module:
Stich, Michael; Prof. Dr. rer. oec.

Courses (Type of course, Weekly hours per semester), Instructor:
Accounting - Exercise (MGTHN0131) (Vorlesung, 2 SWS)
Stich M

Accounting - Lecture (MGTHN0131) (Vorlesung, 2 SWS)
Stich M
For further information in this module, please click campus.tum.de or here.

Module Description

MGTHN0133: Entrepreneurship and Family Enterprise | Entrepreneurship and Family Enterprise

Version of module description: Gültig ab summerterm 2023

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Grading based on a written examination of 90 minutes (100%). The written form of the exam allows a comprehensive assessment of the competences gained by the participants and their understanding of the basic principles of entrepreneurship and family enterprise.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
The module introduces participants to the essential principles, concepts, and methods of entrepreneurship and family enterprise. The module captures the following topics:
• Definitions, regional aspects, and special forms of entrepreneurship, including personality, creativity, idea devel-opment, cognition, opportunity recognition, decision making, affect, and moving forward from failure of entrepre-neurial individuals
• Entrepreneurial companies, including growth strategies, strategic alliances, and resources
• Family entrepreneurship as the most important innovation driver and sustainable value creator of the German economy and aspects related to founding, operating, and succeeding a family enterprise
• Process of opportunity recognition and development, including teamwork, applying concepts to real-world prob-lems, presenting insights, and discussing results
• Basic problems, arguments, and theoretical approaches of business ethics

Intended Learning Outcomes:
After successfully completing the module, participants have gained the competence to:

• explain the basic concepts of entrepreneurship, including basic definitions, psychological processes and char-acteristics of the entrepreneur, and potential development paths of young companies,
• reflect about the specific challenges and sets of family entrepreneurship,
• transfer essential knowledge and theoretical frameworks of the entrepreneurial process to real world cases, and to
• decide on ethical matters in business drawing on established ethical theories and concepts.

Teaching and Learning Methods:
The lecture provides essential knowledge on entrepreneurship and family enterprise. Discussions and active partici-pation is encouraged. The exercise allows working in smaller groups and to apply the theoretical basics to real-world problems. Additional background is provided through self-studying related scientific literature.

Media:
Lecture slides and exercises available in TUM Moodle

Reading List:
• Crane and Matten. 2003. Business ethics: A European perspective
• Hisrich, Peters, and Shepherd. 2010. Entrepreneurship
• Read, Sarasvathy, Dew, Wiltbank, and Ohlsson. 2010. Effectual e

Responsible for Module:
Bird, Miriam; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Entrepreneurship and Family Enterprise - Lecture (MGTHN0133) (Vorlesung, 2 SWS)
Bird M

Entrepreneurship and Family Enterprise - Exercise (MGTHN0133) (Übung, 2 SWS)
Kaufmann L
For further information in this module, please click campus.tum.de or here.

Module Description

MGTHN0135: Marketing | Marketing

Version of module description: Gültig ab summerterm 2023

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Grading based on a written multiple-choice examination of 90 minutes (100%) with 35 multiple-choice assignments. In the examination, participants are allowed to use a non-programmable calculator. The final grade can be enhanced by one third of a grade through successful mid-term assignments.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
The module introduces the goals, tasks, and instruments of the marketing mix and introduces to fundamentals of marketing theory and practice. The module outlines why marketing plays a central role for every company and its success. The module also addresses how marketing tasks and instruments are continuously changing in the context of the digital transformation and how to consider ethical aspects when deciding on marketing activities. The module is structured as follows:
• Subject and basic concepts of marketing
• Branding
• Product policy and product innovation
• Pricing policy
• Communication policy and social media marketing
• Distribution policy

Intended Learning Outcomes:
After successfully completing the module, participants have gained the following competences:

• Ability to summarize the core elements of the marketing management process
• Ability to apply important theories, models, and strategies for building brand equity
• Ability to explain and apply goals and instruments of product policy and new product development
• Ability to explain and apply characteristics and elements of pricing policy, communication policy, and social media marketing
• Ability to design distribution systems
• Ability to apply data science and artificial intelligence to analyze consumer behavior, optimize marketing strate-gies, and enhance customer engagement
• Ability to discuss and argue for alternative ways of organizing, developing, and implementing practical marketing projects and to consider environmental and ethical effects
• Ability to reflect on and discuss central aspects in relation to the marketing research literature

Teaching and Learning Methods:
The module consists of a lecture with integrated exercises. The lecture explains the theoretical and conceptual basics of marketing. In the exercise, the gained competences are trained based on practical assignments. Participants will be asked to read the literature before the lecture and to prepare for each lecture using provided texts and slides. Partici-pants will be enabled to relate the provided materials to decision making in practice, by means of examples and cas-es. Participants are encouraged to contribute to the lecture by giving a short presentation about a current research topic.

Media:
Lecture slides, exercises, and journal articles available in TUM Moodle

Reading List:
• Blythe and Martin. 2019. Essentials of marketing
• Kotler and Keller. 2021. Marketing management
• Sudhir and Toubia. 2023. Artificial intelligence in marketing

Responsible for Module:
Meißner, Martin; Prof. Dr. rer. pol.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

MGTHN0137: Microeconomics | Microeconomics

Version of module description: Gültig ab winterterm 2023/24

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Grading based on a written examination of 90 minutes (100%). Participants have to demonstrate their ability to ade-quately apply and interpret microeconomic concepts and methods.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
None

Content:
The module introduces to the essential concepts of microeconomics. It deals with the behavior of individual econom-ic units (e.g., households, companies, and public institutions) and how these economic units interact to form markets and industries. Important questions discussed in the module:
• How can consumer decisions be explained and how can aggregate demand be derived from consumer choice?
• Which are the factors that determine the production decisions of companies?
• How do equilibrium prices emerge in competitive markets and how in monopoly markets?
• What is the effect of government interventions in markets?
• How does market power affect social welfare?
• Which factors lead to market failure?

Intended Learning Outcomes:
After successfully completing the module, participants have gained the competence to:
• describe economic tradeoffs, in particular of consumers and companies in scarcity situations,
• solve tradeoffs and to apply these approaches to new situations,
• explain fundamental economic mechanisms underlying specialization and trade,

in particular in the context of technological progress,
• predict governmental interventions and how they affect simple competitive markets,
• explain why certain industries are prone to market concentration and how market power affects social welfare, and
• distinguish which types of goods are efficiently provided on free markets and which not.

Teaching and Learning Methods:
The module consists of an interactive lecture which introduces essential microeconomic concepts and theories. The lecture illustrates them with topical empirical examples. Classroom experiments nudge participants to put themselves into the position of specific economic players, thereby requiring them to actively reflect the concepts discussed. Online surveys at the end of each topic enable participants to select which topics they would like to intensify in sub-sequent classes. In the accompanying exercise, participants practice mathematical techniques needed to develop a deeper understanding of economic concepts by applying them to specific problems and examples. A textbook ena-bles the participants to repeat the concepts and to apply them to additional examples.

Media:
Textbook, lecture slides, exercises, classroom experiments, and online surveys available in TUM Moodle

Reading List:
Pindyck and Rubinfeld. 2013. Microeconomics.

Responsible for Module:
Lergetporer, Philipp; Prof. Ph.D.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

WIHN0219_E: Investment and Financial Management | Investment and Financial Management

Version of module description: Gültig ab winterterm 2019/20

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** summer semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The grading is based on a written exam with a duration of 120 minutes. The exam covers all material from both the lecture (Corporate Finance) and the exercise (Mathematical Basics in Finance). To test whether the students acquired the theoretical basics in financial analysis and investment planning, multiple-choice questions are asked, where they have to find the correct or incorrect statement among several alternative statements. By using a calculator and the formulary issued by the chair, the students for example have to analyze investment projects, create the optimal capital structure of projects or firms, evaluate bonds, stocks, or equity options to demonstrate their ability to apply financial tools based on finance theory and to critically analyze different problem sets which finally results in a context-based conclusion.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
Lecture in Corporate Finance
The lecture will give students a broad understanding of the instruments to analyze and evaluate investment opportunities. The following topics are discussed:Financial Statement Analysis (balance sheet analysis, analysis of profit and loss account), Investment Analysis (net present value method, internal rate of return, other methods), Capital Budgeting (determination of free cash flows, choosing between alternatives), Cost of Capital (equity costs, borrowing costs, weighted average cost of capital), Capital Structure (including influencing factors and the importance of taxes).

Exercise on Mathematical Basics
The exercise deals with the active and practical use of mathematics in finance, with particular focus on the calculation ofinterests and asset pricing. The following topics are covered: Interests, Annuities, Redemptions, Bond, Stocks and Options.

Intended Learning Outcomes:
Lecture in Corporate Finance
Upon completion of the lecture students will be able to name and apply important measures of company performance indicators, determine an optimal capital structure for companies and value investment projects in a world without taxes (Modigliani-Miller) and with taxes. This will allow them to analyze and evaluate investment opportunities. Students will be able to understand and analyze companies' investment decision-making process and to create investment as well as capital budget plans. Furthermore, students will be able to remember and understand key theories of corporate finance and to apply fundamental methods of corporate finance that sets the fundamental basis for the overall module.

Exercise on Mathematical Basics
The primary learning goals of the exercise are to 1) introduce students to the concepts in financial mathematics; 2) introduce students to financial instruments as they relate to financial mathematics; 3) introduce students to the use of mathematical models for financial products; 4) develop student abilities to create and apply mathematical models. The specific content goals are the understanding of: the concepts of bond, stocks, and financial derivative products; the time value of money; compound interest; annuities; loan concepts and amortization; mathematics of financial products.

Teaching and Learning Methods:
The weekly lecture contains presentations of theoretical basics and applied examples, supported by slides. For a better learning experience and to enhance the understanding of the course content, the lectures are supported by a) smaller exercises that are discussed in class, and b) quiz questions at the end of sessions. In addition, through real-life examples and various calculation questions that are discussed in class, the exercise on mathematical basics deepens the understanding of interest, annuities, and financial assets. Depending on availability, there might be an additional optional exercise for students which discusses the answers to MC questions/problem sets that are related to both the lecture and exercise content.

Media:
Exercise sheets, PowerPoint

Reading List:
Berk/DeMarzo (2023), Corporate Finance, 6th. Edition, Pearson.

If applicable, further literature will be announced at the first session.

Responsible for Module:
Müller, Sebastian; Prof. Dr. rer. pol.

Courses (Type of course, Weekly hours per semester), Instructor:
Investment and Financial Management (WIHN0219_E) - Exercise (Übung, 2 SWS)
Gong Z, Osterrieder D

Investment and Financial Management (WIHN0219_E) - Lecture (Vorlesung, 2 SWS)
Müller S
For further information in this module, please click campus.tum.de or here.

Electives in General Studies | Wahlmodule Überfachliche Grundlagen

Module Description

CITHN50001: Intercultural Jumpstart Seminar | Intercultural Jumpstart Seminar

Version of module description: Gültig ab winterterm 2022/23

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 60	**Contact Hours:** 30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination is a project work in which students interview foreign students based on the ‘critical incidents technique’ and write a written report to summarize the experience, example situations and individual learning. In this way, the students demonstrate that they are able to understand the impact of cultural differences and analyze intercultural situations. By describing their individual learning, they also demonstrate their increased awareness of their own cultural background.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
None

Content:
The seminar sensitizes the students to cultural customs. On the one hand, the seminar imparts knowledge about different cultures and their customs, on the other hand, it strongly encourages reflection and thus invites an intensive examination of one's own and foreign cultures. It addresses cultural differences, the emergence of stereotypes and prejudices, reflects cultural action from a systemic perspective, imparts knowledge about psychological dynamics within intercultural conflicts and teaches techniques essential to respectful and non-judgmental interaction in an intercultural environment.

Intended Learning Outcomes:
After successful completion of the course, the students have a basic understanding of the impact of cultural differences on university and professional life and the interaction between personality, situational, and cultural aspects. They know about stereotypes and prejudice, intercultural competence and related concepts like ‘cultural humility.’
Students are able to analyze intercultural situations, take on different perspectives, and work on a non-judgemental attitude. They can transfer scientific concepts to everyday situations, such as the ‚cultural pendulum technique to solve intercultural situations.
They have increased awareness of their own cultural background and reactions in intercultural situations and can reflect upon their own unconscious biases.

Teaching and Learning Methods:
Discussions, Exercises in small groups, Interview with foreign student based on the ‘critical incidents technique’

Media:
Lecture slides, handouts, exercise sheets

Reading List:
Will be announced during the course

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Intercultural Jumpstart (MGTHN0161) (Seminar, 2 SWS)
N N
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN50002: Buddy Program Campus Heilbronn | Buddy Programm Campus Heilbronn

Version of module description: Gültig ab winterterm 2022/23

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 30	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Business simulation, report, participation in the quality cycle of the buddy program, active participation (ECTS: 3, no grade)

Repeat Examination:

(Recommended) Prerequisites:
Participation possible after the end of the 2nd semester

Content:
The Buddy Program trains students in their social skills and enables them to gain initial experience in leading and managing small groups:

Trainings:
Therefor the content of the program includes training on the Code of Conduct and training on how to deal with international freshmen.

Be a Buddy:
During the semester, the students are assigned to a group of freshmen. The students take responsibility for the members of the group. The members of the group are mentored by the student individually and during group activities.

Individual care:
Buddies keep in touch with their protégés and provide them with individual support as they start their studies and gain a foothold in Germany, sometimes even before they come to Germany.

A buddy maintains an exchange at eye level with his buddies in order to make the support personal and authentic (peer education). The buddy decides how private the exchange is to be.

Independent supervision of the group:
Students independently design, organize and plan activities for their group. Regular contact with a buddy's buddy group promotes encounters between freshmen from a wide variety of subjects.

Business simulation:
In a business simulation, the students learn to organize themselves in a company-analogous manner and to independently design, organize and implement events for the entire buddy family.

Intended Learning Outcomes:
The Buddy Program teaches students:
- To provide extracurricular support for first-semester students/buddies studying internationally – partly even before they arrive in Germany
- To carry out integration work and to sensitize first semester students/buddies to international students for cultural customs
- To independently design, organize and carry out activities and events for the assigned small group of international freshmen students/buddy groups
- Taking responsibility for leading your own small group of international freshmen students/buddy groups
- Taking on representative activities during events (e.g. "Welcome Day")
- To independently establish company-analogous structures in order to realize excursions, events and activities for the entire buddy family

Teaching and Learning Methods:
Training courses in which individual and group work take place, business simulation, peer education during the supervision of the buddy group

Media:
Training material (buddy guide, slides)

Reading List:
Will be announced during the course

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

CITHN50004: Design Thinking (English) | Design Thinking (English)

Version of module description: Gültig ab summerterm 2025

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 75	**Contact Hours:** 15

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
At the end of the course a written examination is administered. The learning outcomes are examined by single-choice-questions with rationales and open-ended questions to test that students can explain key concepts, compare design thinking tools, and apply these to concrete problems. The duration of the final written examination is 90 minutes.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
None

Content:
Design Thinking – Customer-centered Approach to Solving Complex Problems

1 Introduction
• History and relevance of the topic
• Theoretical foundations
• Application example and outlook

2 Theoretical foundations
• Design Thinking concepts
• Rules and principles
• Areas of performance

3 Design Thinking Process
• Theoretical foundations
• Design Thinking Process

• Practical example

4 Empathize
• Practical example
• Observations
• Surveys
• Basic Concepts

5 Define
• Methods
• Design Thinking Process
• Practical example

6 Ideate
• General rules
• Methods for generating ideas
• Creativity Techniques

7 Prototype
• Prototyping Process
• Categories
• Analog tools
• Digital Tools

8 Test
• Methods
• The Five Act Interview

9 Reflection and Outlook
• Recap
• Related Approaches
• Design Sprint
• Outlook

Intended Learning Outcomes:
During the course, students will learn various methods and tools of design thinking. Learning/ qualification objectives to be achieved and competencies to be taught to students include:

• Students will know and be able to explain key terms, processes, methods, and tools of design thinking.
• The students are able to apply tools of Design Thinking to concrete problems.
• Students will be able to compare design thinking tools based on their application knowledge in order to assess which ones are best suited for concrete problems.

• Students will be able to transfer design thinking approaches to unfamiliar contexts involving interdisciplinary teams.
• Students will be able to use design thinking tools to understand problems in a user-centered way and develop solution ideas, prototype them, evaluate them using user feedback, and summarize the findings.

Teaching and Learning Methods:
The theoretical basics for achieving the learning outcomes should mainly be conveyed through different learning units in an online course.
For every chapter there is a
• Introduction video for a first overview on the learning outcomes of the chapter
• Detailed video with slides and voice over
• Transcript of the detailed video
• Interview with a design-thinking-expert of the industry about the contents of the chapter
• A quiz with learning control questions, enabling the students to test their knowledge themselves.
This way, students are not only given the opportunity to impart knowledge but also to take an active role in order to ensure optimal learning success.

The interaction between students and professors takes place though weekly virtual office hours, regular announcements and an online forum.

Media:
Online-course

Reading List:
Will be announced during the course.

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Design Thinking (English) Campus Heilbronn (CITHN50004) (Vorlesung, 2 SWS)
Matthes F
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN50005: Basics Sustainability | Basics Sustainability

Version of module description: Gültig ab winterterm 2022/23

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 90	**Contact Hours:** 0

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
At the end of the course, there is a written exam for which students are free to choose two of the four course chapters. The exam is competency-based and includes both comprehension and calculation tasks to test that students are able to understand and apply sustainability concepts. The duration of the exam is 45 minutes.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
None

Content:
The consistent overstepping of planetary boundaries by humans is the cause of many environmental problems and social tensions regionally, globally and between generations. For sustainable development in the sense of a fair distribution of resources, an interdisciplinary approach to solutions and the consideration of the interrelationships of social, ecological and economic factors and actors are indispensable. The course "Basics Sustainability" teaches the most important sustainability models and analysis methods for sustainable development. From environmental and resource economics, basic methods for a fair distribution of environmental goods as well as environmental policy instruments and tools for sustainable spatial design are presented. With regard to materiality, the goal is the use of renewable raw materials for the production of materials and products, the recycling or pollutant-free landfilling of existing products and materials, and the optimization of natural processes from a material and energy point of view. Against the background of climate change, students learn about current technologies and developments and assess measures in the field of renewable energy systems in the context of grid expansion, energy distribution and storage technologies.

1. General principles of sustainability
1.1 Introduction to sustainability
1.2 Social transformation
1.3 Corporate responsibility
1.4 Sustainability management
1.5 Life cycle assessment
1.6 Education for sustainable development

2. Economic framework for sustainability
2.1 Fundamentals of resource, environmental and public good economics
2.2 Sustainability policy
2.3 Game theory and behavioural economics in the context of sustainability
2.4 Economics of climate change
2.5 Sustainable regional development

3. Materiality and sustainability
3.1 Resource consumption and finiteness
3.2 Primary/secondary biomass and material cycles
3.3 Materials from renewable resources
3.4 Recycling and biorefinery concepts

4. Energy and sustainability
4.1 Introduction to energy and sustainability
4.2 Climate change and greenhouse effect
4.3 Fundamentals of selected technologies
4.4 Future energy systems

Intended Learning Outcomes:
General principles of sustainability: At the end of the module students know about the interrelationships of social, ecological and economic factors and actors and are able to apply basic sustainability models and analysis methods.

Economic framework of sustainability: Students know methods of environmental and resource economics and are able to assess the use of sustainability policy instruments.

Materiality and sustainability: Students understand the material cycles of the earth and the production of materials from renewable raw materials and the recycling and disposal of products.

Energy and sustainability: Students understand the basics of climate change. They know about current technologies and developments andare able to assess measures in the field of regenerative energy systems in the context of grid expansion, energy distribution and storage technologies.

Teaching and Learning Methods:
The theoretical basis for achieving the learning outcomes in this online course is mainly taught through various learning units. This is done by text form in combination with graphics, diagrams and videos. In each chapter, learning control questions serve to repeat the material learned; calculation and transfer tasks deepen understanding. In this way, students are not only given the opportunity to impart knowledge but also to take an active role to ensure optimal learning success. Interaction with the lecturers and other course participants takes place in a moderated online forum.

Media:
Online-course

Reading List:
Current literature references are provided in the online course.

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Basics Sustainability Campus Heilbronn (CITHN50005) (Vorlesung, 2 SWS)
Matthes F
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN50007: Ethical and Moral Aspects of Corporate Management | Ethical and Moral Aspects of Corporate Management

Version of module description: Gültig ab summerterm 2025

Module Level: Bachelor/Master	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 60	**Contact Hours:** 30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Final presentation (50%), term paper (50%):

During the seminar, the students should not limit themselves to the analysis of challenges, but should produce their own solutions through interdisciplinary cooperation and thus assume social responsibility. In order to reach an extended level of knowledge, the participants first receive expert input. In the further course of the seminar, the students form small groups that concentrate on sub-areas of the overriding task. Throughout the seminar, these groups reconvene to present each other's progress and receive feedback, which is then incorporated into the small group work. The students summarize their results in a small individual term paper (3 pages) and a final group presentation (approx. 5 minutes per student). After the seminar, the final results are awarded and evaluated.

Repeat Examination:

(Recommended) Prerequisites:
None

Content:
The course covers ethical and moral aspects of corporate management.
The spatial dynamization of the post-reunification period, the global interaction, and the digitization of industrial production represent some of the challenges that the individual has to face in the 21st century. AI and Metaverse are pushing into everyday life simultaneously. A tension emerges between machine and human being, which raises essential questions. How can these challenges be mastered? What is the main focus and the perspective? The seminar aims at a management-oriented ethical-moral foundation and values in entrepreneurship. Morality is shaped by our beliefs

and values. People make decisions or react based on their conscious but also unconscious value system. What is allowed and what is forbidden? In the family, in the company, in society? And does that fit with our own expectations and alignments? Personality formation as a reflected social construct refers to our moral canon. The value orientation and standard systems are not only decisive for the development of individual leadership skills, but they also cultivate a successful corporate culture. During the seminar, students learn to question and reflect on critical processes. After a theoretical input, the participants will be confronted with practical examples in a workshop and have the opportunity to present their final results in the plenum and to have personal discussions with managers. How to form a value-based and leadership-oriented enterprise architecture in today's pluralized world and how ethics and morality model our identity are the core topics that the seminar will address.

Intended Learning Outcomes:
On the technical side, the participants should deepen their knowledge and skills in width and in a special field. In addition, their methodological and analytical skills, in particular their ability to process complex problems, should be recessed. The seminar introduces students to interdisciplinary perspectives and working methods and prepares them for areas of application across the entire spectrum of responsible corporate management.

This includes, in particular, the ability to model a value-based leadership role and the ability to quickly familiarize yourself with new areas of application. The participants gain an overall view of a complex topic, which enables them to recognize interdisciplinary and intercultural connections.

In addition to technical qualifications, the seminar also deepens key qualifications. Great importance is attached to the ability to make presentations, to self-reliance, the ability to work in a team, knowledge and experience in project management and, within the scope of the possibilities to personal management qualifications.

The ability to critically reflect on one's own work and the willingness to take responsibility for the results of this work are promoted. Students are made aware of the need to consider technical, economic, and ethical and moral conditions when using digital systems.

Teaching and Learning Methods:
Lectures, Discussions, Exercises and workshops in groups

At the beginning of the seminar, prior knowledge is activated and the level of perception is determined. The lecturers introduce the students to the topic and arouse interest and concrete expectations. Using a flashlight method, teaching content, teaching environment and general mood are reflected. After detailed theoretical input, case studies are presented that are based on events or sequences of events in concrete and exemplary situations from the professional field. Based on the case material, the students should independently develop a solution to the given problem. They should analyze facts, identify problems, and obtain and evaluate information. Thematic and analytical group discussions lay the foundation for making decisions. The students present the results of practical examples, case studies and group work in the plenary session.

After the final results are presented, knowledge is developed through discussions and the diversity of opinions on a topic is made transparent. This promotes students' intellectual participation and deepens their understanding of the topic. Through independent implementation and the associated action-oriented learning, students acquire professional skills and practice transferring their knowledge to new fields of application independently and on their own responsibility. During the seminar, constant attention is paid to selfreflection, which is intended to guide students to reflect on their behavior honestly, responsibly and critically. At the end of the seminar, the final results are evaluated, the previous knowledge is compared with the knowledge gain and additional self-reliant learning is pointed out. A written paper, which consists of an independent theoretical work on a clear task from the subject area, serves to deepen the topic and consolidate the knowledge already acquired.

Media:
Lecture slides and worksheets

Reading List:
Hausman, Daniel, (2016): “Economic Analysis, Moral Philosophy, and Public Policy”, Cambridge University, Press (Verlag).
Luhmann, Niklas, (2017): “Trust and Power”, Wiley.
Maturana, Humberto, (1992). “The tree of knowledge. Biological basis of human understanding”, Boston: New York: Shambhala.
Moriarty, Jeffrey, (2021): “Business Ethics: A contemporary Introduction (Routledge Contemporary Introductions to Philosophy)”, New York, NY: Routledge
Wieland, Josef, (2016): “Governance Ethics: Global value creation, economic organization and normativity”, Springer VS, Heidelberg.

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Ethical and moral aspects of intercultural corporate management (WIHN1198) (Seminar, 2 SWS)
N N
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN5009: Disentangling Sustainability in IT | Disentangling Sustainability in IT

Version of module description: Gültig ab summerterm 2024

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 60	**Contact Hours:** 30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
At the beginning of the seminar, each participant receives a specific topic and research paper dealing with sustainability in IT, either on a conceptual level or in specific detail. On this, the students prepare a scientific essay using scientific literature. The essay should have a minimum of 8 and a maximum of 15 pages. The results of the work will be presented to the other participants of the seminar in oral form (max. 45 mins), supported by visual media, such as slides. Also evaluated is how the students respond to questions, suggestions, and discussion points to their work and presentation and how they engage in the discussion of other students' work and presentations. In doing so, the students demonstrate their expertise in critically analyzing the presented scientific content. The various components are weighted for calculating the module grade as follows: 40% written elaboration, 40% presentation, 20% participation.

Repeat Examination:

(Recommended) Prerequisites:
-

Content:
Various facets of sustainability, from a very abstract perspective down to concrete considerations e.g. in the area of Business Process Management, will be investigated in thematic blocks.
These blocks include but are not limited to:
- Green Business Process Management
- Digital technology affordances for sustainable business practices
- Sustainability-oriented business process analysis and re-design
- Green adaptation of process-based applications
- Energy efficiency testing to improve environmental goals of software

- Eco-efficiency maturity models

Intended Learning Outcomes:
At the end of the seminar, students have the necessary methodological and interdisciplinary skills to independently engage with advanced topics in the area of sustainability and IT. Furthermore, the students are capable of engaging critically with scientific literature and are able to involve in discussions on scientific literature. They are capable of writing a scientific report and give a scientific presentation.

Teaching and Learning Methods:
The module consists of two parts: First, slide-supported presentations provide preliminary knowledge regarding the module's topic, as well as regarding scientific methods, which will be discussed in plenary. Subsequently, participants independently elaborate on a scientific topic. The accompanying presentation and written elaboration are supposed to capture the core concepts of the topic and to engage critically with it. Further, the participants present their results and discuss them with other participants, placing their own work in a broader context.

Media:
Slides

Reading List:
• Giddings, B., Hopwood, B. and O'Brien, G. (2002) 'Environment, economy and society: fitting them together into sustainable development', Sustainable Development, 10(4), pp. 187–196. Available at: https://doi.org/10.1002/sd.199.
• Purvis, B., Mao, Y. and Robinson, D. (2019) 'Three pillars of sustainability: in search of conceptual origins', Sustainability Science, 14(3), pp. 681–695. Available at: https://doi.org/10.1007/s11625-018-0627-5.
• Johnston, P. et al. (2007) 'Reclaiming the definition of sustainability', Environmental science and pollution research international, 14(1), pp. 60–6. Available at: https://doi.org/10.1065/espr2007.01.375.
• Hueting, R. and Reijnders, L. (2004) 'Broad sustainability contra sustainability: the proper construction of sustainability indicators', Ecological Economics, 50(3–4), pp. 249–260. Available at: https://doi.org/10.1016/j.ecolecon.2004.03.031.

Responsible for Module:
Pufahl, Luise; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Disentangling Sustainability in IT (CITHN5009) (Seminar, 2 SWS)
Klessascheck F, Oliveira da Nobrega Costa A, Pufahl L
For further information in this module, please click campus.tum.de or here.

Module Description

CITHN5010: Soft Skills and Tools for Studies and Career in IT | Soft Skills and Tools for Studies and Career in IT

Version of module description: Gültig ab winterterm 2024/25

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** irregularly
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 60	**Contact Hours:** 30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
For examination, the students will prepare a learning portfolio which will make 100% of the final grade. Each student will create his/her own learning portfolio consisting of maximum 1 page for each learning unit. This page includes a brief summary of the learning unit, a visualization of what has been learned, and a list of key learnings.
Since each learning unit consists also of an interactive part in which students have to actively participate in the seminar. Thus, it is essential for the success of the portfolio that students, for example, also give a presentation about a small topic and review others, participate in the Design Thinking project, and apply scientific methods. Without an active participation, the reflection part of the portfolio cannot be fulfilled. The learning diary is submitted digitally at the end of the semester. This form of examination ensures the consolidation of what has been learned and creates space for reflection on each learning unit.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
No prerequisites are required. However, the event is aimed at first and second-semester students of the Bachelor's program in Information Engineering.

Content:
Various topics relevant to soft skills and tools that help the students in their studies and future career are covered. The following topics will be presented and discussed with the students:
• Team work and conflict management (Helps the students for the upcoming project work in e.g. practical courses)

• What makes a good (scientific) presentation? Which techniques can we use? (This course unit prepares students for presentations, not only for their studies, but also for their future job. A change of perspective enables students to take on the position of evaluator)
• User-centered innovation with design thinking
• Research – what is it and how does it work? (This learning unit gives students important tips on the structure of scientific papers, how to read them and where to find them)
• Helpful tools (This learning unit provides an overview of everyday tools that make everyday (university) life easier. Examples are Zotero, GitHub/GitLab, various IDEs, LaTeX)
• ChatGPT in studies - possibilities and limitations (This learning unit is intended to familiarize students with the use of ChatGPT)

Intended Learning Outcomes:
Students acquire relevant social and technical skills for their
academic and professional careers. They can create presentations, present them in front of a group, and evaluate them based on criteria such as structure, content, and presentation style. Additionally, students can describe the stages of group work, identify potential conflicts in team dynamics, and apply strategies to address these conflicts effectively.
Furthermore, students understand the fundamentals of Design Thinking and academic research methods and gain experience in utilizing databases such as Google Scholar, dblp, WebOfScience. Moreover, they gained practical experience with tools relevant to computer science, such as GitHub and literature management tools (Citavi, Zotero etc.).
Students can take structured notes on lecture content, visualize these notes, and engage in reflective practices.

Teaching and Learning Methods:
The teaching method is divided into two parts per learning unit (2x 90 min synchronous). First, basic ideas, terms and concepts are explained in a keynote format supported by slides or by student presentations. In the second part, the students will work in groups on the learning content (teams of 3-4 people). After each learning unit, the students then summarize the learning unit asynchronously in individual work on one page and reflect on what they have learned. This results in the learning diary, which is assessed as an examination achievement. The oral presentation is prepared by the students individually.

Media:
PowerPoint presentations (slides), online materials such as links, books, papers, media set

Reading List:
- Edward D. Zanders: Presentation Skills for Scientists: A Practical Guide. Cambridge University Press. Second Edition. 2018
- Jan Recker: Scientific Research in Information Systems: A Beginner’s Guide. Springer International Publishing. Second Edition. 2021
- Enkelejda Kasneci et al.: ChatGPT for good? On opportunities and challenges of large language models for education. Learning and Individual Differences, Volume 103. 2023
- Patricia Elgoibar et al.: Conflict management. Oxford research encyclopedia of psychology. 2017.

- Walter Brenner et al.: Design thinking as mindset, process, and toolbox: Experiences from research and teaching at the University of St. Gallen. Design thinking for innovation: Research and practice, 2016.

Responsible for Module:
Pufahl, Luise; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:
Soft Skills and Tools for Studies and Career in IT (CITHN5010) (Seminar, 2 SWS)
Andree K, Pufahl L
For further information in this module, please click campus.tum.de or here.

Module Description

INHN0030: Ethics for Nerds | Ethik für Nerds

Version of module description: Gültig ab summerterm 2025

Module Level: Bachelor/Master	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 60	**Contact Hours:** 30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination is a research paper (10-15 pages, 50% of the overall grade), supplemented by a presentation (approx. 30 minutes; 50% of the overall grade). In the presentation students should present their results of a relevant case study on a current socially relevant topic in computer science. This includes both the technical background as well as the socio-scientific approach from an ethical perspective. In the plenary session, the topic is discussed in detail, whereby participation in the discussion also counts towards the examination grade. The topics are further explored in the seminar paper. It is demonstrated that students are able to apply the necessary knowledge regarding the social relevance of the topic as well as different ethical evaluation criteria in general terms.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
no

Content:
Topics comprise: * Information and communication technologies whose invention and also the timing of their invention have had a lasting impact on our society. From this point of view, today's technologies such as the World Wide Web or social media will be considered from an ethical point of view and a look into the future will be taken. * How dependent are we on emerging technologies? Safety critical systems are by no means always safe, which can be well observed in numerous incidents. What happens, for example, when self-driving cars are controlled by third parties due to a security vulnerability? Is such dependence even justifiable from an ethical point of view? * What influence do the new media have on the individual? What drives young people to give everything to look good in a virtual world? * How should the influence of social media on politics and society be looked at? After the initial euphoria, critical voices are increasingly being

raised. * Within this context, it is worth taking a closer look at the topic of "fake news" within the context of image and language manipulation. * How justifiable is it at all to work on information technology for modern weapons systems? * The gambler of tomorrow: What is happening "thanks to computer science" on the international financial markets?

Intended Learning Outcomes:
After successfully completing the module, students will be able to critically and reflectively discuss and assess the social effects, expectations and consequences in the context of a concrete case study in computer science and include them in their decision making in terms of responsible ethics.

Teaching and Learning Methods:
The module is divided into two parts: First, basic knowledge about the subject area is elaborated and discussed in the seminar through presentations using slides. In the next step this knowledge is further deepened and compiled in the seminar thesis. Each participant works out his or her slides and thesis individually.

Media:
Slide show, thesis, possibly blackboard

Reading List:
Sara Baase: A Gift of Fire: Social, legal, and ethical issues for computing
Deborah Johnson: Computer Ethics (3rd Edition, 2001)
Deborah Johnson: Engineering Ethics: Contemporary and Enduring Debates (2020)
Herman Tavani: Ethics and Technology: Controversies, Questions, and Strategies for Ethical Computing (5th edition, 2016)

Responsible for Module:
Trinitis, Carsten; Prof. Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Ethik für Nerds (INHN0030) Campus Heilbronn (Seminar, 2 SWS)
Trinitis C
For further information in this module, please click campus.tum.de or here.

Bachelor's Thesis and Colloquium | Bachelor´s Thesis und Bachelorkolloquium

Module Description

INHN0024: Bachelor's Thesis | Bachelor's Thesis

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 12	**Total Hours:** 360	**Self-study Hours:** 360	**Contact Hours:** 0

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Type of Assessment: Research Elaboration
The Bachelor's Thesis is a written scientific report with a duration of 4 months, where the students apply research methods to elaborate a specific scientific topic in information systems and report the results. The Bachelor’s Thesis shall verify that students are able to apply the knowledge and methodological skills acquired during the studies to a specific topic in this area. It should be between 30 and 60 pages.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Obligatory bachelor courses, selected elective courses

Content:
The Bachelor's Thesis focuses on a research topic in information engineering. The Thesis is always supervised by a professor of TUM Department of Informatics, often in co-operation with an industry partner. The topic of the thesis is designed in a way that it can be treated extensively and parallel to the Bachelor Project within five months.

Intended Learning Outcomes:
At the end of the module "Bachelor's Thesis" students are able to elaborate a scientific topic in an autonomous and systematic way. The students are able to become acquainted with a scientific topic. They have learned to understand a specific scientific question and apply scientific methods to answer the question. The students are able to discuss their results in a critical way.

Teaching and Learning Methods:
The creation of the thesis requires the students to deal soundly with a scientific subject. Therefore they apply the knowledge and methodological skills acquired during the studies and create an elaborated scientific report within the set time frame.

Media:
Literature, presentations

Reading List:
Specific literature based on the topic

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

Module Description

INHN0025: Bachelor's Colloquium | Bachelorkolloquium

Version of module description: Gültig ab winterterm 2021/22

Module Level: Bachelor	**Language:** English	**Duration:** one semester	**Frequency:** winter/summer semester
Credits:* 3	**Total Hours:** 90	**Self-study Hours:** 89	**Contact Hours:** 1

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Type of Assessment: Presentation
The Bachelor Colloquium has a duration of 30 minutes. In the first 15 minutes the students present the results of their Bachelor's Thesis. With regard to the Bachelor's Thesis, the Bachelor Colloquium shall verify that students can reflect on the research question, the concepts, and the methods that are used in the area of information systems and that students can present the results of the Bachelor's Thesis. Furthermore, the Bachelor Colloquium consist of a disputation with a duration of 15 minutes that shall verify that students are able to defend their own scientific work and its practical realization and to argue their decisions and judgments.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
A student is admitted for the Bachelor Colloquium as soon as the student has successfully completed the Bachelor's Thesis.

Content:
The Bachelor Colloquium comprises the presentation of the Bachelor's Thesis and a disputation in which the students will be asked questions about their presentation and the broader topic in which their presentation is embedded.

Intended Learning Outcomes:
At the end of the module "Bachelor Colloquium" students are able to present a scientific topic in an autonomous and systematic way. The students are able to defend their own scientific work and to argue their decisions and judgments.

Teaching and Learning Methods:
Elaboration of the contents of the Bachelor's Thesis to a presentation, that gives a clear outline of the achieved results in the thesis, and preparation for a scientific discussion of the presented work

Media:
literature, presentations

Reading List:
specific literature based on the topic

Responsible for Module:
Matthes, Florian; Prof. Dr. rer. nat.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click campus.tum.de or here.

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