TECHNISCHE UNIVERSITÄT DARMSTADT

Explanation:

Below you will find a tabular overview of the compulsory and core courses of the degree programme "Bachelor of Science in Computer Science" of the Department of Computer Science at TU Darmstadt, including a short description of the learning content. Please add to the table in the right-hand column the successfully completed courses/modules of your previous degree programmes in which, in your view, equivalent content to the corresponding courses was provided. It is not necessary for admission that all listed courses have been covered in terms of content.

Please do not submit course description handbooks in paper form or on CD. If you would like to submit a course description handbook or relevant excerpts thereof to supplement your information, please send these documents to application@informatik.tu-darmstadt.de, stating your application number.

Compulsory and core courses of the degree programme "Bachelor of Science in Computer Science" of the Department of Computer Science at TU Darmstadt	**Successfully completed courses with equivalent content**
Functional and Object-oriented Programming Concepts: • Basic concepts of programming languages • Foundations of functional programming languages • Foundations of object-oriented programming languages • Design and implementation of small software systems • Basic type systems • Fundamental data structures and algorithms and their complexity • Recursion • Simple I/O • Basics of testing • Documenting source code	**Problem Solving and Programming in C** • Program Development Life Cycle -Programming Languages - Compilation - Linking and Loading - Testing and Debugging - Documentation - Control Structures – Algorithmic Problem Solving. • Structure of C program - C programming • Introduction to Arrays • Introduction to Functions • Pointers – Pointer Operators – Pointer Arithmetic – Arrays and Pointers- swapping of Two Numbers using Pass by Reference. • Structures and File processing
Algorithms and Data Structures: • Data structures: array, list, binary search tree, B- tree, graph representation, hash table, heaps Algorithms: sorting algorithms, string matching, graph traversal, insertion, search, and deletion for data structures, shortest path search, minimal spanning trees • Asymptotic complexity: run times, Big O notation, complexity classes P and NP, NP completeness • Algorithmic strategies. for example: Divide-and-Conquer, dynamic programming, brute-force, greedy, backtracking, meta heuristics	**Data Structures & Algorithms** • Basic terminologies and introduction to algorithm. • Array - Stack – Operations - Evaluating Arithmetic Expressions - Conversion of Infix to Postfix Expression - Queue – Circular Queue – DeQueue - Operations - • Linked_List and its Types - Various Representations - Applications of Linear Data Structures. • Trees – Tree Traversals - Binary Tree - Threaded Binary Tree - Binary Search Tree - B & B+ Tree - AVL Tree - Splay Tree • Graph - Directed - Undirected -Graph Search and Traversal Algorithms - Operations & Applications of Non-Linear Data Structures. • Sequential Search - Binary Search - Breadth First Search - Depth First Search • Insertion Sort - Selection Sort - Shell Sort - Divide and Conquer Sort – Merge Sort - Quick Sort - Heapsort. • File Organisation- Hashed and Various Types of Accessing Schemes •

Digital Design: • Digital Design: digital abstraction and its technological realization, number systems, logic gates, MOSFET transistors and CMOS gates, power consumption • Combinational Logic Design: boolean equations and algebra, mapping equations to gates, multi-level logic circuits, four-valued logic (0,1,X,Z), logic minimization, combinational building blocks, timing • Sequential Logic Design: latches, flip-flops, synchronous logic design, finite-state machines, timing, parallelism • Hardware Description Languages: modeling of combinational and sequential circuits, structural modeling, modeling of finite-state machines, data types, parametrized modules, testbenches • Digital Building Blocks: arithmetic circuits, fixed-/floating-point representations, sequential building blocks, memory arrays, logic arrays	
Computer Organisation: • Architecture of Microprocessors: programming in assembly and machine language, addressing modes, tool flows, run-time environment • Microarchitecture: instruction set and architectural state, performance analysis, microarchitectures with single-cycle/multi-cycle/pipelined execution, exception handling, advanced microarchitectures • Memory and I/O-Systems: performance analysis, caches, virtual memory, I/O techniques, standard interfaces	

Parallel programming: • Foundations of parallel systems • Parallel architectures • Programming models for parallel computing • Parallel algorithms • Significant practical programming exercises covering the above topics • If necessary introduction to base programming languages	
• Operating Systems: • Introduction to Operating Systems (OS) - Role, purpose and design issues • Processes and Threads - OS structures, process control, abstractions, kernel/user modes and operations, context switching, interrupts • Inter-Process Communication - Message passing IPC, RPC, layers, interfaces, hierarchies • Coordination: Deadlocks - Process coordination, critical sections, deadlock characterization, deadlock detection and recovery, deadlock avoidance • Scheduling/Resource Management - Task ordering, preemptive and non-preemptive scheduling, schedulers and policies, OS implementations • Concurrency: Races, Mutual Exclusions - Critical sections, races, spin locks, synchronization • Programming Abstractions: Semaphores - Semaphores, Monitors • Memory Management - Storage structures, management/replacements approaches, virtual memory, paging, caching, segmentation • I/O - Device management, drivers, segmentation, interrupt handling, DMA • File systems - File systems requirements, design and implementation, file structures, directories, naming, partitions, virtual file systems • Fault Tolerance/Resilience - Fault types, fault handling approaches, reliable message delivery, OS reliability and availability, security issues • Embedded/RT OS - Memory/disk/performance management, recovery, fault-tolerances, real-time aspects	**Operating Systems** • Computer System Overview and Operating system overview, Programs, OS Generation and System Boot. • Processes, CPU Scheduling, Threads, Synchronization, Deadlock • Main Memory – Background, Swapping, Contiguous Memory Allocation, Paging, Segmentation, Segmentation with paging, 32 and 64-bit architecture. • Virtual Memory – Background, Demand Paging, Page Replacement, Allocation, thrashing; Allocating Kernel Memory, OS Examples • Mass Storage system, File-System Interface, File system mounting, File Sharing and Protection; File System Implementation, I/O Systems, • Linux System - Design Principles, Kernel Modules, Process Management, Scheduling, Memory Management, Input-Output Management, File System, Inter-process Communication; Mobile OS - iOS and Android - Architecture and SDK Framework, Media Layer, Services Layer, Core OS Layer, File System

• Distributed OS - Distributed computation and communication abstractions, synchronization, coordination, consistency • Virtual Machines - Purpose and types of virtualization, virtual file systems, Hypervisors	
Introduction to Compiler Construction: • Structure of compilers • Context-free grammars for the description of language syntax • Lexing and parsing techniques • Intermediate representations • Semantic analysis • Run-time organisation • Code generation • Software tools for compiler constructions • Implementation techniques for compilers	
Automata, Formal Languages and Decidability: • Introduction: transition systems, words, languages • Basic mathematical methods and proof patterns • Finite automata and regular languages, determinism and nondeterminism, closure properties and automata constructions, Kleene Theorem, Myhill-Nerode Theorem, pumping lemma • Grammars and the Chomsky hierarchy, context-free languages, pumping lemma, CYK algorithm; • Models of computation: PDA and Turing machines • Decidability and recursive enumerability in the Chomsky hierarchy	
Propositional Logic and Predicate Logic: • syntax and semantics of propositional logic, functional completeness and normal forms, compactness, complete proof calculi: resolution and a sequent calculus • Syntax and semantics of first-order logic, structures and assignments, normal forms, skolemization, Herbrand theorem, compactness,	

complete proof calculi: (ground) resolution and a sequent calculus, Gödel's Completeness Theorem • Undecidability of first-order logic; • optional: digressions on expressiveness and model checking	
Formal Methods in Software Design: • Modelling of concurrent software with the ProMeLa language • Formalisation of safety and liveness properties in propositional temporal logic • Theoretical Foundations of Model Checking • Verification of ProMeLa programs using the model checker SPIN • Syntax, semantics, and sequent calculus for typed first-order logic • Foundations of the contract-based software specification language JML • Dynamic logic as a first-order program logic • Formal software verification by symbolic execution and invariant reasoning • Tool-based verification of Java programs with the verification system KeY	
Computer Networks and Distributed Systems: • Foundations: Services, protocols, connection, layer model • Role of link layer, network layer, transport layer, application layer • Basic mechanisms (algorithms, protocols) for multiplexing, broadcast, multicast, routing and forwarding • Quality of service and reliability: definition and mechanisms • Coordination in distributed systems: from primitives to applications • Selected internet protocols and technology	**Computer Networks** • Networks – Types – Protocol Layering – TCP/IP Protocol suite – OSI Model – Physical Layer: Performance – Transmission media – Switching-Packet Switching. • Link-Layer Addressing – DLC Services – Data-Link Layer Protocols – HDLC – PPP - Media Access Control - Wired LANs: Ethernet - Wireless LANs – Introduction – IEEE 802.11, Bluetooth – Connecting Devices. • Network Layer Services – Packet switching – Performance – IPV4 Addresses – Forwarding of IP Packets - Network Layer Protocols: IP, ICMP v4 – Unicast Routing Algorithms – Protocols – Multicasting Basics – IPV6 Addressing – IPV6 Protocol. • Introduction – Transport Layer Protocols – Services – Port Numbers – User Datagram protocol – Transmission Control Protocol – SCTP. • WWW and HTTP – FTP – Email –Telnet –SSH – DNS – SNMP.
Computer Security: Part I: Cryptography • Background in mathematics for cryptography • Security objectives: Confidentiality, Integrity, Authenticity	**Cryptography and Network Security** • Security trends and Security policies. • Mathematics of symmetric key cryptography • Symmetric key ciphers: sdes • Mathematics of asymmetric key cryptography • Asymmetric key ciphers – SHA –Digital signature and authentication protocols – DSS-Entity Authentication: Biometrics, Passwords,

	Challenge Response protocols- Authentication applications - Kerberos, X.509 • Electronic Mail security – PGP, S/MIME – IP security – Web Security – SYSTEM SECURITY: Intruders – Malicious software – viruses – Firewalls.
• Symmetric and asymmetric cryptography • Hash functions and digital signatures • Protocols for key distribution Part II: IT-Security and Dependability • Basic concepts of IT security • Authentication • Access control models and mechanisms • Basic concepts of network security • Basic concepts of software security • Basic concepts of web security • Dependable systems: error tolerance, redundancy, availability	
Information Management: Part 1: Structured data / databases Data Modeling: • Conceptual data models (ER / UML structure diagrams) • Conceptual design • Logical data model (relational model) • Mapping from conceptual to logical model Relational query languages: • SQL (in detail) • Relational Algebra Database theory: • Functional dependencies • Design theory and normalization Implementation of database systems: • Physical data storage • Query processing and optimization • Transaction processing Current trends in databases: • Main-memory databases & Column-based data storage • NoSQL databases • Big Data Systems	**Database Management Systems** • Purpose of Database System –Database System Architecture-Data Models– Entity Relationship Model – ER Diagrams – Enhanced ER Model. • Relational Model-ER-to-Relational Mapping– Keys –Relational Algebra • SQL Fundamentals – Advanced SQL features – Embedded SQL– Dynamic SQL-Functional Dependencies • Non-loss Decomposition • Transaction Concepts – ACID Properties – Schedules – Serializability – Concurrency Control – Need for Concurrency – Locking Protocols – Two Phase Locking • RAID – File Organization – Organization of Records in Files – Indexing and • Hashing –Ordered Indices – B+ Tree Index Files – B Tree Index Files • Static Hashing – Dynamic Hashing – Query Processing Overview – Algorithms for SELECT and JOIN operations – Query optimization using Heuristics

Part 2: Unstructured Data / Text Processing Basics of unstructured data: • Storage and encoding of unstructured text • Creating and annotating text corpora • Lexical resources and knowledge bases Natural Language Processing: • Segmentation • Syntactic and semantic analysis • Other Applications for unstructured data: • Information Retrieval • Information Extraction Advanced Topics: • Introduction to research data management • Data curation and visualization • Documentation and archiving	
Software Engineering: • Requirements Analysis • Domain Modelling • Object-oriented Analysis and Design • Software Architecture • Software Quality, in particular: o Verification (among others, testing and static analysis) o Software Metrics • Design Patterns • Refactoring • Software Evolution and Software Variability	Software Engineering • Introduction to Software Engineering, Perspective and Specialized Process Models Software Requirements, Requirement Engineering Process, • Classical analysis: Structured system Analysis, Petri Nets- Data Dictionary. • Architectural Design, User Interface Design • Software testing Fundamentals • Regression Testing • Coding practices • Software Project Management • Make/Buy Decision COCOMO I & II Model • Earned Value Analysis Planning – Project Plan, Planning Process, RFP Risk Management • RMMM Plan-CASE TOOLS
Modeling, Specification and Semantics: • Models and their significance for Computer Science • Introduction to discrete modeling using mathematical logic and algebraic concepts • Interpretation and faithfulness of formal models • Abstraction, refinement, composition, and decomposition of models • Systematic construction of models and deliberate design decisions • Syntax and operational semantics of programming languages • Introduction to specification languages	

• Syntax and denotational semantics of formal specification languages • Elementary proof techniques and their use • Modeling of systems and of requirements • Modeling of coordination and communication in concurrent systems	
Visual Computing: • Basics of perception • Basic Fourier transformation • Images, filtering, compression & processing • Basic object recognition • Geometric transformations • Basic 3D reconstruction • Surface and scene representations • Rendering algorithms • Color: Perception, spaces & models • Basic visualization	**Computer Vision** • Computer Vision and Computer Imaging Systems, Image Formation and Sensing • Fundamentals of Image Formation • Fourier Transform - Convolution and Filtering – Image Enhancement - Restoration - Histogram Processing. • Edges - Canny - LOG, Line Detectors (Hough Transform), Corners - Harris and Hessian Affine, Orientation Histogram - SIFT, HOG, SURF, Scale - Space Analysis Image Pyramids and Gaussian derivative filters, Gabor Filters and DWT. • Region Growing - Edge Based approaches to segmentation - Graph-Cut - Mean- Shift - MRFs, Texture Segmentation - Object detection - 3D object recognition - 3D reconstruction - Introduction to Motion - Parametric motion – Spline based motion. • **C**lustering
Introduction to Artificial Intelligence Foundations: • Introduction, History of AI • Intelligent Agents Search: • Uninformed Search • Heuristic Search • Local Search • Constraint Satisfaction Problems • Games: Adversarial Search Planning: • Planning in State Space • Planning in Plan Space Decisions under Uncertainty: • Uncertainty and Probabilities • Bayesian Networks Decision Making	**Fundamentals of Artificial Intelligence** • Introduction–Definition - Future of Artificial Intelligence – Characteristics of Intelligent Agents– Typical Intelligent Agents – Problem Solving Approach to Typical AI problems • Heuristics- Informed Local Search Algorithms and Optimization Problems • First Order Predicate Logic • Ontological Engineering • Planning: Non-linear Planning, Conditional planning, Reactive planning, Implementation of block world • Problem AI applications – Language Models – Information Retrieval- Information Extraction – Natural Language Processing - Robot – Hardware – Perception.

Machine Learning: • Neural Networks • Reinforcement Learning Philosophical Foundations	Types of Machine learning – Supervised – Un-supervised – Reinforcement Learning types – Applications of Machine learning techniques with Case study– Banking and Finance – Healthcare – Insurance – Issues in Machine learning
Probabilistic methods in computer science: • Basics from probability theory, statistics and information theory. • Probabilistic approaches to graph-based modeling in computer science • Basic probabilistic problems and use of probabilistic methods o in practical computer science (e.g. run-time analysis of programs, data compression), o in technical computer science (e.g., reliability of hardware, caching), and o in applied computer science (e.g., simulation of stochastic systems, probabilistic robotics). • Selected randomized algorithms, their analysis by 'The Probabilistic Method', algorithms for automated decision making and optimization • Application of probabilistic methods in artificial intelligence (e.g. learning methods, neural networks) and data science • Implementation of probabilistic methods by means of practical programming examples	**Probability and Statistical Modelling (III Semester)** • Probability – Axioms of probability – Conditional probability – Baye's theorem • Discrete and continuous random variables – Moments – Moment generating functions. • Binomial, Poisson, Geometric, Uniform, Exponential, Erlang and Normal distributions. • Joint distributions – Marginal and conditional distributions – Covariance – Multinomial distribution –Bivariate normal distribution – Central limit theorem (• Simple linear regression and correlation, multiple regression and multiple correlation. • Test of hypothesis – concept and formulation, Type I and Type II errors, • Neyman Pearson lemma, Procedures of testing. Analysis of Variance • Sign test, Wilcoxon signed rank test, Mann-Whitney test, Run test, Kolmogorov-Smirnov test, Spearman's and Kendall's test. Tolerance region. • Point estimation, criteria for good estimates (un-biasedness, consistency), • Methods of estimation including maximum likelihood estimation. • Basics of Time Series: Stationary, ARIMA Models: Identification, Estimation and Forecasting.
Scientific Computing: • Fundamentals of scientific modeling and "The Scientific Method". • Modeling and system description using the example of mechanical systems • Problem specification for the simulation of complex models • Model building and identification using the example of mechanical systems • Model analysis of static systems by numerical methods for the solution of linear and nonlinear systems of equations • Model analysis and simulation of dynamic models by initial value problems with ordinary differential equations	

• Implementation of models and simulations using examples e.g. from robotics and other fields • Validation of models and simulations using measured data • Applications in the simulation and control of robots as well as physics-based animation and computer games	
Mathematics I (for Computer Science): • Sets, relations, functions, groups, basic algebraic structures • Modular arithmetic, RSA algorithm for encrypting data • Finite dimensional vector spaces, linear maps and matrices, Gauss algorithm, determinants, eigenvalues • Basics: real and complex numbers • Sequences and convergence	**Engineering Mathematics (I Semester)** • Symmetric, skew symmetric and orthogonal matrices; • Eigenvalues and Eigenvectors of a real matrix • Diagonalization of a Quadratic form using orthogonal transformation • Limits, continuity, Differentiation rules partial derivatives (first and second order – basic problems), • Taylor's series for functions of two variables, Jacobian, • Integration by parts, Integration of rational functions by partial fraction, Integration of irrational functions • Double integrals – Change of order of integration – Double integrals in polar coordinates • Power series – Taylor's series – series for exponential, trigonometric, logarithmic, hyperbolic functions – Fourier series – Half range Sine and Cosine series – Parseval's theorem
Mathematics II (for Computer Science): • Series and power series • Standard functions • Real functions and continuity • Differential calculus, extremal values, inverse function • Exponential function and logarithm • Integration: integrals, Fundamental Theorem of Calculus, techniques of integration • Real functions of several variables • Taylor and Fourier series • Ordinary differential equations, elementary techniques an examples, linear differental equations	**Discrete Structures (II Semester)** • Binary Relation, Partial Ordering Relation, Equivalence Relation • The Principles of Mathematical Induction-The Well-Ordering Principle –Pigeonhole principle – Permutation – Combination. • The Laws of Logic, Logical Implication • Proof Techniques • Algebraic Structures with One Binary Operation • Algebraic Structures with two Binary Operations • Boolean Algebra • Graphs and their properties • Rooted Trees