COMPUTER SCIENCE (COMP_SCI)

COMP_SCI 310-0 Scalable Software Architectures (1 Unit)
Teaches software design principles for building high-scale Internet services. Focuses on challenges arising when assembling software services that run on many machines in parallel and which require the coordination of multiple software applications.
Prerequisites: COMP_SCI 213-0, COMP_SCI 214-0.

COMP_SCI 314-0 Technology and Human Interaction (1 Unit)
Understanding human interactions that occur both with and through technology; design, creation, and evaluation of technologies to support such interactions.

COMP_SCI 315-0 Design, Technology, and Research (1 Unit)
Hands-on experience in the research learning environment. Students lead research projects in social and crowd computing, cyber-learning, human-computer interaction, and artificial intelligence.
Prerequisite: consent of instructor (by application only).

COMP_SCI 321-0 Programming Languages (1 Unit)
Introduction to key parts of programming languages: syntax, semantics, and pragmatics. Implementation of a series of interpreters that show how various aspects of programming languages behave.
Prerequisites: COMP_SCI 111-0, COMP_SCI 214-0.

COMP_SCI 322-0 Compiler Construction (1 Unit)
The compiler is the programmer's primary tool. Understanding the compiler is therefore critical for programmers, even if they never build one. Furthermore, many design techniques that emerged in the context of compilers are useful for a range of other application areas. This course introduces students to the essential elements of building a compiler: parsing, context-sensitive property checking, code linearization, register allocation, etc. To take this course, students are expected to already understand how programming languages behave, to a fairly detailed degree. The material in the course builds on that knowledge via a series of semantics preserving transformations that start with a fairly high-level programming language and culminate in machine code.
Prerequisite: COMP_SCI 213-0.

COMP_SCI 323-0 Code Analysis and Transformation (1 Unit)
Fast, highly sophisticated code analysis and code transformation tools are essential for modern software development. Before releasing its mobile apps, Facebook submits them to a tool called Infer that finds bugs by static analysis, i.e., without even having to run the code, and guides developers in fixing them. Google Chrome and Mozilla Firefox analyze and optimize JavaScript code to make browsers acceptably responsive. Performance-critical systems and application software would be impossible to build and evolve without compilers that derive highly optimized machine code from high-level source code that humans can understand. Understanding what modern code analysis and transformation techniques can and can't do is a prerequisite for research on both software engineering and computer architecture since hardware relies on software to realize its potential. In this class, you will learn the fundamentals of code analysis and transformation, and you will apply them by extending LLVM, a compiler framework now in production use by Apple, Adobe, Intel and other industrial and academic enterprises.
Prerequisite: COMP_SCI 213-0.

COMP_SCI 325-1 Artificial Intelligence Programming (1 Unit)
Introduction to LISP and programming knowledge-based systems and interfaces. Strong emphasis on writing maintainable, extensible systems. Topics include semantic net-works, frames, pattern matching, deductive inference rules, case-based reasoning, and discrimination trees. Project-driven. Substantial programming assignments.
Prerequisite: COMP_SCI 110-0, COMP_SCI 111-0, or programming experience.

COMP_SCI 330-0 Human Computer Interaction (1 Unit)
Introduction to human-computer interaction and design of systems that work for people and their organizations. Understanding the manner in which humans interact with and use computers for productive work.
Prerequisite: programming experience.

COMP_SCI 331-0 Introduction to Computational Photography (1 Unit)
Fundamentals of digital imaging and modern camera architectures. Hands-on experience acquiring, characterizing, and manipulating data captured using a modern camera platform.

COMP_SCI 335-0 Introduction to the Theory of Computation (1 Unit)
Mathematical foundations of computation, including computability, relationships of time and space, and the P vs. NP problem.
Prerequisite: COMP_SCI 212-0 or consent of instructor.

COMP_SCI 336-0 Design & Analysis of Algorithms (1 Unit)
Analysis techniques: solving recurrence equations. Algorithm design techniques: divide and conquer, the greedy method, backtracking, branch-and-bound, and dynamic programming. Sorting and selection algorithms, order statistics, heaps, and priority queues.
Prerequisite: COMP_SCI 111-0, COMP_SCI 212-0, or consent of instructor.

COMP_SCI 337-0 Natural Language Processing (1 Unit)
Semantics-oriented introduction to natural language processing, broadly construed. Representation of meaning and knowledge inference in story understanding, script/frame theory, plans and plan recognition, counter-planning, and thematic structures.
Prerequisite: COMP_SCI 348-0 or consent of instructor.

COMP_SCI 338-0 Practicum in Intelligent Information Systems (1 Unit)
A practical excursion into building intelligent information systems. Students develop a working program in information access, management, capture, or retrieval. Project definition, data collection, technology selection, implementation, and project management.

COMP_SCI 339-0 Introduction to Database Systems (1 Unit)
Data models and database design. Modeling the real world: structures, constraints, and operations. The entity relationship to data modeling (including network hierarchical and object-oriented), emphasis on the relational model. Use of existing database systems for the implementation of information systems.
Prerequisites: COMP_SCI 214-0 and (COMP_SCI 213-0 or COMP_ENG 205-0).

COMP_SCI 340-0 Introduction to Networking (1 Unit)
A top-down exploration of networking using the five-layer model and the TCP/IP stack, covering each layer in depth. Students build web clients, servers, and a TCP implementation and implement routing algorithms.
Prerequisites: COMP_SCI 214-0 and (COMP_SCI 213-0 or COMP_ENG 205-0).

COMP_SCI 341-0 Mechanism Design (1 Unit)
Applying algorithms and microeconomics to derive a theory of the design of mechanisms that produce desired outcomes despite counteractive inputs by outside agents. Key application areas: auctions, markets, networking protocols.

COMP_SCI 343-0 Operating Systems (1 Unit)
Fundamental overview of operating systems, including: concurrency (processes, synchronization, semaphores, monitors, deadlock); memory management (segmentation, paging virtual memory policies); software system architectures (level structures, microkernals); file systems

(directory structures, file organization, RAID); protection (access control, capabilities, encryption, signatures, authentication). Requires substantial programming projects.
Prerequisites: Both COMP_SCI 214-0 and COMP_SCI 213-0, or COMP_SCI 214-0 and COMP_ENG 205-0.

COMP_SCI 344-0 Design of Computer Problem Solvers (1 Unit)
Principles and practice of organizing and building artificial intelligence reasoning systems. Pattern-directed rule systems, truth-maintenance systems, and constraint languages.
Prerequisites: COMP_SCI 348-0 and COMP_SCI 325-1 or equivalent LISP experience.

COMP_SCI 345-0 Distributed Systems (1 Unit)
Basic principles behind distributed systems (collections of independent components that appear to users as a single coherent system) and main paradigms used to organize them.
Prerequisites: COMP_SCI 213-0 and COMP_SCI 214-0.

COMP_SCI 348-0 Introduction to Artificial Intelligence (1 Unit)
Core techniques and applications of AI. Representing, retrieving, and applying knowledge for problem solving. Hypothesis exploration. Theorem proving. Vision and neural networks.

COMP_SCI 349-0 Machine Learning (1 Unit)
Study of algorithms that improve through experience. Topics typically include Bayesian learning, decision trees, genetic algorithms, neural networks, Markov models, and reinforcement learning. Assignments include programming projects and written work.
Prerequisite: COMP_SCI 348-0.

COMP_SCI 350-0 Introduction to Computer Security (1 Unit)
Basic principles and practices of computer and information security. Software, operating system, and network security techniques, with detailed analysis of real-world examples. Topics include cryptography, authentication, software and operating system security (e.g., buffer overflow), Internet vulnerability (DoS attacks, viruses/worms, etc.), intrusion detection systems, firewalls, VPN, and web and wireless security.
Prerequisite: COMP_SCI 213-0 or equivalent or consent of instructor; COMP_SCI 340-0 highly recommended.

COMP_SCI 351-1 Introduction to Computer Graphics (1 Unit)
Mathematical software and hardware requirements for computer graphics systems. Data structures and programming languages. Random displays. Graphic applications.
Prerequisite: COMP_SCI 214-0.

COMP_SCI 351-2 Intermediate Computer Graphics (1 Unit)
Methods and theory of computer graphics. Project-oriented approach. Describing shapes, movement, and lighting effects; interactive elements.
Prerequisites: COMP_SCI 214-0 and COMP_SCI 351-1.

COMP_SCI 352-0 Machine Perception of Music & Audio (1 Unit)
Machine extraction of musical structure in audio and MIDI and score files, covering areas such as source separation and perceptual mapping of audio to machine-quantifiable measures.
Prerequisite: COMP_SCI 211-0, GEN_ENG 205-2, or prior programming experience in MATLAB.

COMP_SCI 354-0 Computer System Security (1 Unit)
The past decade has seen an explosion in the concern for the security of information. This course introduces students to the basic principles and practices of computer system and networking security, with detailed analysis of real-world examples and hands-on practice. Topics include the basic crypto, authentication, reverse engineering, buffer overflow attacks, vulnerability scanning, web attacks, firewalls, intrusion detection/prevention systems, etc. We will first introduce the basic theory for each type of attack; then we will actually carry them out in 'real-world' settings. The goal is to learn security by learning how to view your machine from a hacker's perspective. In addition, we encourage students to participate in the UCSB International Capture the Flag Competition. Capture the Flag is a network security exercise where the goal is to exploit other machines while defending your own. In fact, this course should prepare you for any one of many capture the flag competitions that take place year-round. We will learn about different types of hacks and perform them. After learning how to execute such exploits and penetrate a network, we will discuss ways to protect a network from others exploiting the same vulnerabilities. Understanding security is essential in all fields of software development and computing. For major or minors in Computer Science, this course can satisfy the system breadth.

COMP_SCI 355-0 Digital Forensics and Incident Response (1 Unit)

COMP_SCI 367-0 Wireless and Mobile Health: Passive Sensing Data Analytics (1 Unit)
A hands-on introduction and experience to the growing field of mobile Health. Students work together on a project with clinicians and faculty in medicine, building a unique mHealth system while testing their system on a small population. Theory-driven project hypothesis, technology selection and development, passive sensing data analytic chain understanding and implementation, and project management.

COMP_SCI 370-0 Computer Game Design (1 Unit)
Plot, narrative, and character simulation for creating game worlds; artificial intelligence for synthetic characters; tuning gameplay. Substantial programming and project work.
Prerequisites: COMP_SCI 214-0; 1 unit of COMP_SCI 322-0, COMP_SCI 343-0, COMP_SCI 348-0, or COMP_SCI 351-1, COMP_SCI 351-2.

COMP_SCI 371-0 Knowledge Representation and Reasoning (1 Unit)
Principles and practices of knowledge representation, including logics, ontologies, commonsense knowledge, and semantic web technologies.
Prerequisite: COMP_SCI 348-0, COMP_SCI 325-1, or equivalent experience with artificial intelligence.

COMP_SCI 376-0 Computer Game Design and Development (1 Unit)
Introduction to design of simulation-based media, with an emphasis on 2D game design. Mathematical preliminaries: linear, affine, and projective spaces, linear transforms, inner and exterior products, unit quaternions; Architecture: update/render loop, component systems, serialization and deserialization, event handling and asynchronous processing, multitasking; Rendering: scene graphs, meshes, shaders, sprites; Networking; Audio; Physics: particles, rigid bodies, collision detection; Gameplay design.
Prerequisite: COMP_SCI 214-0.

COMP_SCI 377-0 Game Design Studio (1 Unit)
In this course, students will design and develop games using the Unity game engine, with focus on team-based projects and agile development practices. Lectures will cover game design theory, game architecture and implementation, and the business of game development. Students will participate in class discussion and evaluation of projects in progress, to develop their skills in iterative design and implementation.
Prerequisite: COMP_SCI 376-0.

COMP_SCI 393-0 Software Construction (1 Unit)
Building software is a craft that requires careful design. This course teaches software design principles in a studio setting. Each week, students present their programs to the class for review. Together, the class evaluates the programs for correctness and, more importantly,

clarity and design. Expect to learn how to build reliable, maintainable, extensible software and how to read others' codes.
Prerequisites: COMP_SCI 111-0 and COMP_SCI 214-0.

COMP_SCI 394-0 Agile Software Development (1 Unit)
Developing mobile and web applications, using modern sustainable agile practices, such as backlogs, user stories, velocity charts, and test driven development, to deliver value as quickly as possible to end users, clients, developers, and the development organization.

COMP_SCI 396-0 Special Topics in Computer Science (1 Unit)
Projects suggested by faculty and approved by the department. Equivalent to 397 but intended to apply toward courses for the computer science major and its project requirement.

COMP_SCI 397-0 Special Projects in Computer Science (1 Unit)
Topics suggested by faculty and approved by the department. Equivalent to 396 but intended to apply toward courses for the computer science major.

COMP_SCI 401-0 Introduction to Graduate Studies (1 Unit)
An introduction to graduate studies in Computer Science aimed at preparing incoming doctoral students to perform great research, regardless of area, and providing an overview of research areas in computer science at Northwestern through short presentations by faculty.

COMP_SCI 409-0 Swarms and Multi-Robot Systems (1 Unit)
This class surveys the state of the art research in robotic swarms, looking at both algorithms for controlling them and current hardware implementations. It also addresses the deficiencies keeping them from every-day use. Coursework includes reading research papers, student presentations and discussion of select papers, and projects implementing studied topics in a real or simulated robot swarm.
Prerequisite: Permission of Instructor. Cross-listed with MECH_ENG 409-0.

COMP_SCI 410-0 Autonomous Quadrotor Design and Control (1 Unit)
Centered around a project where teams create and program an autonomous quadrotor robot, this class focuses on advanced embedded control of an electromechanical system. Topics include: programming interfaces between an embedded computer and external sensors/actuators, programming a timing-critical control loop for stable flight, and creating a software stack that interacts with low-level code to create a desired high-level behavior.
Prerequisite: Permission of Instructor. Cross-listed with MECH_ENG 410-0.

COMP_SCI 413-0 Tangible Interaction Design and Learning (1 Unit)
Explores the use of tangible interaction to create innovative learning experiences, including distributed cognition, embodied interaction, cultural forms, and design frameworks.
Prereq: COMP_SCI 110-0 or COMP_SCI 111-0.

COMP_SCI 430-0 Design of Interactive Learning Environments (1 Unit)
Design of computer-based "learning-by-doing" environments. Course focuses more on initial conception of learning environments than on technical issues involved in building these environments.

COMP_SCI 431-0 Human Perception and Electronic Media (1 Unit)

COMP_SCI 440-0 Advanced Networking (1 Unit)
This course will cover a broad range of topics including Internet evolution and architectures; analysis and design of network protocols (both wired and wireless); networking issues for Web and gaming applications; analysis and performance of content distribution networks; network security, vulnerability, and defenses.
Prerequisites: COMP_SCI 340-0 or permission of instructor.

COMP_SCI 441-0 Resource Virtualization (1 Unit)
The bulk of the time in this class examining a virtual machine monitor (VMM) in depth, at the source code level. The course explains the hardware/software interface of a modern x86 computer in detail. A VMM is an operating system that is implemented directly on top of the hardware interface, and itself presents a hardware interface to higher-level software. Students will also acquire valuable kernel development skills.
Prerequisites: COMP_SCI 213-0.

COMP_SCI 443-0 Advanced Operating Systems (1 Unit)
Advanced concepts in operating systems and distributed computing from historical perspectives to current themes such as peer-to-peer computing and mobile systems.

COMP_SCI 445-0 Internet-scale Experimentation (1 Unit)
Explores the challenges of large-scale networked system experimentation and measurement.

COMP_SCI 446-0 Kernel and Other Low-level Software Development (1 Unit)
The development of low-level systems software such as drivers, kernels, etc is very different from the development of applications. This class teaches how such development is done: how to design, implement, debug, and optimize low-level software and use available tools.
Prerequisites: (COMP_SCI 213-0 or COMP_ENG 205-0) and (COMP_SCI 343-0 or COMP_ENG 361-0 or COMP_ENG 366-0 or COMP_ENG 466-0) or permission of Instructor.

COMP_SCI 450-0 Internet Security (1 Unit)
Through measurement-based approaches, students analyze the complexity of the Internet, and develop countermeasures against various vulnerabilities of the Internet such as viruses, worms, and denial of service attacks.

COMP_SCI 455-0 Distributed Computing Systems (1 Unit)
Fundamentals and systems design aspects of distributed systems, paradigms for distributed computing, client-server computing, concurrency control, distributed file systems, resource management, high-performance computing aspects.
Prerequisites: COMP_SCI 343-0 or COMP_ENG 361-0.

COMP_SCI 457-0 Advanced Algorithms (1 Unit)
Analysis and design of algorithms; amortized analysis; arithmetic circuits; computational geometry; NP-completeness; approximation algorithms.
Prerequisites: COMP_SCI 336-0 or any algorithms course.

COMP_SCI 469-0 Machine Learning & Artificial Intelligence for Robotics (1 Unit)
A coverage of artificial intelligence, machine learning and statistical estimation topics that are especially relevant for robot operation and robotics research.
Prerequisite: Graduate-level standing (or permission of instructor) for the maths. Some programming experience (in Matlab okay). Undergraduate student enrollment by permission of instructor only.

COMP_SCI 472-0 Designing & Constructing Models with Multi-Agent Language (1 Unit)

COMP_SCI 473-1 NUvention: Web - Part 1 (1 Unit)
NUvention: Web is an interdisciplinary experiential learning program designed to expose students to the entire product and business development life cycle for a software company.

COMP_SCI 473-2 NUvention: Web - Part 2 (1 Unit)

NUvention: Web is an interdisciplinary experiential learning program designed to expose students to the entire product and business development life cycle for a software company.

COMP_SCI 474-0 Probabilistic Graphical Models (1 Unit)
Probabilistic graphical models are a powerful technique for handling uncertainty in machine learning. The course will cover how probability distributions can be represented in graphical models, how inference and learning are performed in the models, and how the models are utilized for machine learning in practice.

COMP_SCI 496-0 Special Topics in Computer Science (1 Unit)
Topics suggested by faculty and approved by the department.

COMP_SCI 497-0 Special Projects in Computer Science (1 Unit)
Project-based course on topics suggested by faculty and approved by the department.

COMP_SCI 499-0 Projects (1 Unit)
Special projects carried out under faculty direction. Permission of instructor and department required.

COMP_SCI 510-0 Seminar (1 Unit)
Seminar on topics of current interest.

COMP_SCI 590-0 Research (1-4 Units)
Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit.