CS - Computer Science

Courses numbered 500 to 799 = undergraduate/graduate. (Individual courses may be limited to undergraduate students only.) Courses numbered 800 to 999 = graduate.

CS 510. Programming Language Concepts (3).
Theoretical concepts in the design and use of programming languages. Formal syntax, including Backus Normal Form (BNF), Extended Backus-Naur Form (EBNF), and syntax diagrams. Semantics, including declaration, allocation and evaluation, symbol table and runtime environment; data types and type checking, procedure activation and parameter passing, modules and abstract data types. Prerequisites: CS 311, MATH 322.

Fundamental principles of modern operating systems. CPU management including processes, threads, scheduling, synchronization, resource allocation and deadlocks. Memory management including paging and virtual memory. Storage management and file systems. Prerequisites: CS 238, 311.

CS 560. Design and Analysis of Algorithms (3).
Design of various algorithms including several sorting algorithms. Analysis of their space and time complexities. Data structures include heaps, hash tables and binary search trees. Prerequisites: CS 322, 400; STAT 460 or IME 254.

CS 594. Microprocessor-Based System Design (4).
3 Classroom hours; 2 Lab hours. Presents knowledge and skills required to design and program microprocessor-based systems. Introduces vendor-supplied special-purpose chips such as interrupt controllers and programmable input/output devices. Laboratory activities give hands-on experience. Prerequisites: CS 238, 394. Corequisite: CS 594L.

CS 665. Introduction to Database Systems (3).
Fundamental aspects of relational database systems, conceptual database design and entity-relationship modeling; the relational data model and its foundations, relational languages and SQL, functional dependencies and logical database design; views, constraints and triggers. Course includes a group project involving the design and implementation of a relational database and embedded SQL programming. Prerequisites: CS 311, MATH 322.

CS 697. Selected Topics (1-3).
1-3 Classroom hours; 0-2 Lab hours. Selected topics of current interest. Repeatable for credit with departmental consent. Prerequisite: departmental consent.

CS 697AG. Introduction to Intelligent Robotics (3).
The study of intelligent robotics allows robots to gather information from surrounding environments and take actions autonomously. Course introduces the fundamental principles and methods of manipulation, navigation and perception for intelligent robotics. Topics covered include geometry transformations, kinematics, dynamics, localization, navigation, mapping, motion planning, intelligent processing, smart sensing, decision making, and robotic intelligence. Explores the robot concepts and algorithms, such as dexterous manipulation, simultaneous localization and mapping (SLAM), and autonomy, while working with Nao humanoid robots and Sawyer collaborative robots. Prerequisites: CS 300, MATH 511, IME 254.

CS 697AN. Hardware-Based Computer Security (3).
Intended for seniors and graduate students who want to study and explore the role of hardware in improving computer security. Topics covered may include (1) elements of computer security, (2) secure coprocessor, (3) secure bootstrap loading, (4) secure memory management, (5) hardware-based authentication, (6) hardware-based virus detection, (7) hardware as a cybersecurity solution, (8) security engineering, (9) managing the development of secure systems, and (10) system evaluation and assurance. Prerequisites: CS 394 and a desire to learn more about both computer architecture and security.

CS 697AP. Applied Parallel Computing (3).
This course is to teach how to program parallel computers to efficiently analyze challenging problems with enormous datasets. Two distinct approaches will be introduced which can be used to solve problems in all manner of domains including data analytics and machine learning. The first approach to be studied will be embarrassingly parallel in nature while the second approach will leverage fine-grain parallelism. Prerequisites: CS 394 or Instructor’s consent.

CS 715. Compiler Construction (3).
First compiler course for students with a good background in programming languages and sufficient programming experience. Covers compiler design, lexical analysis, parsing techniques, symbol tables, scope analysis, type checking and conversion, run-time organization, code generation and optimization. Project-oriented course involves implementation of a full compiler for a simplified but nontrivial procedural language. Prerequisites: CS 238, 510.

CS 720. Theoretical Foundations of Computer Science (3).
Provides an advanced level introduction to the theoretical bases of computer science. Computer science theory includes the various models of finite state machines, both deterministic and nondeterministic, and concepts of decidability, computability and formal language theory. Prerequisite: CS 322.

CS 721. Advanced Algorithms and Analysis (3).
Topics include height-balanced trees, graph algorithms, greedy algorithms, dynamic programming, hard problems and approximation algorithms. Prerequisite: CS 560.

Introductory class on applying various mathematical tools to the field of computer networks and related areas. Divided into three phases: phase one covers the fundamentals of probability, statistics and linear algebra required for understanding the core topics to follow. Phase two covers the core topics of optimization and queuing theory. Phase three briefly covers the advanced topics of game theory and information theory. The depth of coverage is sufficient to allow students to read and understand research papers in computer networking and related areas that use these standard techniques. Ideas are taught through intuition, mathematically correct formalization and detailed numerical examples. Prerequisite: MATH 243. Corequisite: CS 464.

CS 736. Data Communication Networks (3).
Presents a quantitative performance evaluation of telecommunication networks and systems. Includes fundamental digital communications system review; packet communications, queuing theory, OSI, s.25 and SNA layered architectures, stop-and-wait protocol, go-back-N protocol, and high-level data link layer; network layer flow and congestion control, routing, polling and random access, local area networks (LAN); integrated services digital networks (ISDN), and broadband networks. Prerequisite: CS 464.

CS 737. Wireless Networking (3).
Covers topics ranging from physical layer to application layer in the wireless and mobile networking fields. Explores physical layer issues of wireless communications, wireless cellular telephony, ad-hoc networks, mobile IP and multicast, wireless LAN (IEEE 802.11), security, Bluetooth and WAP, etc. Imparts general knowledge about wireless communication technologies and ongoing research activities. Prerequisite: CS 736.
CS 738. Embedded Systems Programming (3).
Studies the requirements and design of embedded software systems. Application of the C programming language in implementing embedded systems emphasizing real-time operating systems, interfacing to assembly and high-level languages, control of external devices, task control and interrupt processing. Prerequisite: CS 594.

CS 750. Workshop in Computer Science (1-5).
Short-term courses with special focus on introducing computer science concepts. Repeatable for credit. Prerequisite: departmental consent.

CS 764. Routing and Switching I (4).
3 Classroom hours; 2 Lab hours. Introductory course which studies different hardware technologies, like Ethernet and token ring. Discusses VLSM. Introduces different routing protocols. Includes hands-on experience in the CS department's routing and switching lab. Prerequisite: CS 464 or 736.

CS 766. Information Assurance and Security (3).
Provides basic concepts in information assurance and security including encryption, digital certificates, security in networks, operating systems and databases. Topics in intrusion detection, legal and ethical issues in security administration are also discussed. Prerequisite: CS 464 or 736 or 764.

CS 767. Foundations of Network Security (3).
Presents fundamental concepts in cryptography and network security, and discusses applications and protocols for providing confidentiality, authentication, integrity, and availability in networking services and systems. Includes review of symmetric-key cryptographic schemes such as DES and AES, public-key cryptographic schemes such as RSA and Diffie-Hellman key exchange protocol, cryptographic hash functions such as SHA, message authentication codes such as HMAC digital signature schemes such as El-Gamal and DSS, kerberos and user authentication protocols, transport layer security and TLS, IP layer security and IPSec, and wireless security principles. CS 766 is highly preferred, but not required. Prerequisite: CS 464 or 736.

CS 771. Artificial Intelligence (3).
Introduces some of the fundamental concepts and techniques underlying artificial intelligence. Topics covered include state spaces, heuristic search, game playing, knowledge representation, and resolution in propositional and first-order predicate logic. Prerequisite: CS 560.

CS 780. Advanced Software Engineering (3).
Discusses advanced topics in software development, maintenance and evolution. Topics include software design patterns, architecture and architectural styles, frameworks, refactorings, and static and dynamic analyses. Includes a group project. Prerequisite: CS 480.

CS 781. Cooperative Education (1-3).
Practical experience in a professional environment to complement and enhance the student's academic program. For master's level CS students. Repeatable for credit, but may not be used to satisfy degree requirements. Prerequisite: departmental consent and graduate GPA of 3.00 or above.

CS 794. Multicore Architectures and Programming (3).
3 Classroom hours. Introduces state-of-the-art concepts and techniques to design and program modern computer systems. Particular attention is given to the following areas: multicore architecture, parallel programming and advanced research. Labs give hands-on experience. Prerequisites: CS 211, 394.

CS 797. Special Topics in Computer Science (1-4).
New or special courses presented on sufficient demand. Repeatable for credit. Prerequisite: departmental consent.

CS 798. Individual Projects (1-3).
Allows beginning graduate students and mature undergraduate students to pursue individual projects of current interest in computer science. Repeatable for credit with advisor approval. Prerequisite: departmental consent.

CS 834. Advanced Routing and Switching (3).
Advanced course which provides an introduction to the Border Gateway Protocol (BGP), the main internet routing protocol, and mobile all-IP-networks. Significant research topics regarding BGP and mobile IP networks are covered. Prerequisite: CS 764.

CS 835. Ad Hoc and Sensor Networks (3).
Teaches the basic techniques, particularly algorithms and protocols used in sensor networks. Exposes students to various sensor network applications and the fundamental issues in designing and analyzing sensor networks. Provides students with a perspective on the active research areas in wireless ad hoc and sensor networks and enhances their potential to do research in this area. Focuses mainly on data intensive sensor networks. Prerequisite: CS 560.

CS 836. Computer Performance Analysis (3).
Teaches the basic concepts in stochastic modeling of systems for analysis and for simulation. Analytic modeling techniques include discrete- and continuous-time Markov chains, queuing theory, and queuing networks, as well as approximate methods based on these techniques. Operational analysis presents a nonstochastic, measurement-based perspective to the analysis of computer systems. Also emphasizes discrete-event simulation, a widely-used technique in many areas of performance evaluation. Performance metrics taken from stochastic simulations are phantom variables, and are subject to the same types of statistical analysis as data obtained from real systems. Prerequisite: EE 754.

CS 837. Energy Intelligent Computing and Communications (3).
3 Classroom hours; 1 Lab hour. Introduces various mobile computing scenarios, explores fundamental causes of energy wastage and addresses means to be more efficient. Looks at how computing can, in general, be carried out in an energy-intelligent manner and be applied to the broader area of cyber-physical systems. Topics covered include: energy as an issue, its relevance to computing and communications, battery technology and mobile device constraints, computing and its role toward achieving broader goals of environmental sustainability. Application areas targeted include mobile computing, cloud computing and smart grids. Course involves team-based research projects targeting these application areas. Prerequisite: CS 464 or 560.

Studies hardware and software features of online multiple computer systems emphasizing network design and telecommunication. Includes distributed databases, interprocessor communication and centralization versus distribution. Studies the use of microcomputers in representative configurations. Prerequisites: CS 540, 736.

CS 862. Advanced Database Systems (3).
Covers recent developments and advances in database technology. Designed for students who have had a first database course and have a good background in the related computer science disciplines. Possible topics include: extended relational database management systems, object-oriented database management systems, deductive databases, database type systems and database programming language, persistent languages and systems, distributed databases. Prerequisite: CS 665.

CS 891. Project (1-3).
Intensive project involving the analysis and solution of a significant practical problem which must be supervised by a CS graduate faculty advisor; it can be job-related. Students must write a report on the project and pass an oral final examination by an ad hoc faculty

CS 894. Multicore Architectures and Programming (3).
3 Classroom hours. Introduces state-of-the-art concepts and techniques to design and program modern computer systems. Particular attention is given to the following areas: multicore architecture, parallel programming and advanced research. Labs give hands-on experience. Prerequisites: CS 211, 394.
committee headed by the project advisor. Prerequisite: departmental consent.

CS 892. Thesis (1-6).
Repeatable for credit up to 6 credit hours. Prerequisite: departmental consent.

CS 893. Individual Reading or Project (1-6).
Enables students to perform self-learning activities under the supervision of a faculty member. Typical activities include reading state-of-the-art topics, performing research tasks, conducting technical projects, and/or similar assignments pertinent to their degree program of study. The course content, objectives, deliverables and evaluation must be documented and must be approved by the supervising faculty and program coordinator/department chair. Repeatable for credit up to 6 credit hours. Prerequisite: departmental consent.

CS 898. Special Topics (2-3).
1-3 Classroom hours; 0-2 Lab hours. Topics of current interest to advanced students of computer science. Repeatable for credit with departmental consent. Prerequisite: departmental consent.

CS 898AG. Software Visualization (3).
Software visualization encompasses the study of graphical metaphors, techniques and tools to represent several aspects of software products, processes, and projects. The visual representations include 2D and 3D. The represented aspects include structural, behavioral, and evolutionary. The course is organized in the form of a research seminar. Students are required to read, present, and review papers from the reading list prepared for the course. The instructor provides the paper review format. Additionally, students need to do a term project (e.g., software prototype development and in-depth literature survey) and submit a 10-page project report in the form of an IEEE two-column proceedings format. Active participation in the class discussion on papers is also an integral part of the class.

CS 898AI. Alternative Computing Paradigm (3).
Computing has been changing its paradigms to fulfill various computation needs. Students learn to understand the present computing systems and then explore some alternative computing paradigms. Topics should include: modern computer systems, optimization techniques for serial code, parallelism and concurrency, parallel computers, parallel computing, quantum computing, chaotic computing and research projects. Students are expected to have adequate knowledge in computer architecture. By continued enrollment in this class, students are certifying that they have met the prerequisite. Prerequisite: at least one of the following: CS 694, CS 738, CS 794, or equivalent.

CS 898AO. Mobile Computing (3).
Covers various research topics in the broad area of mobile computing. Students are exposed to several research challenges faced by mobile computing platforms and associated applications such as intermittent network connectivity, battery and performance constraints, indoor localization and navigation. Each student is expected to work in groups to complete a research project at the end of the class that addresses an outstanding research challenge in the area of mobile computing. Students are also expected to read, present and critique existing research literature in the area. Prerequisites: CS 560, and prior experience programming with Android Studio.

CS 898AR. Machine Learning in Computational Biology (3).
Introduces statistical machine learning algorithms and their applications in computational biology. Intends to achieve two major goals: first, to help students understand the theories of advanced machine learning algorithms; second, to teach students how to apply these cutting-edge machine learning methods to solve problems in life sciences and biomedical research. Students are asked to read and present some selected research papers. They are also required to apply machine learning algorithms to solve real, biological problems in the context of course projects, present the results and document the findings in the form of a final report.

Deep learning is one of the hottest areas in machine learning and is at the core of many recent advances in artificial intelligence, particularly in audio, image, video, and language analysis and understanding. Deep learning is widely deployed by such companies as Google, Facebook, Microsoft, IBM, Baidu, Apple and others for audio/speech, image, video and natural language processing. Course covers a wide variety of topics in deep learning architectures, feature learning and neural computation, including restricted Boltzmann machines, autoencoders, convolutional neural networks etc. Covers mathematical methods and theoretical aspects as well as algorithmic and practical issues. Students have the opportunity to build practical deep neural network architectures and test them on real life datasets in the form of a class project. Prerequisites: CS 560, CS 697AB and good Python programming skills.

CS 898AT. Bitcoins and Cryptocurrencies (3).
Bitcoin is a new and exciting form of cryptocurrency technology that has the potential of altering payments and economics around the world. In between the optimism surrounding Bitcoin's evolution as an alternate form of currency and the pessimism related to its security, success and adoptability, there is significant confusion and lack of understanding at the technical level about the precise architecture and operation of Bitcoin. This advanced graduate-level course attempts to bridge this gap in the technical understanding of Bitcoin and its operation. Specifically addresses the following fundamental questions: How does Bitcoin work and what makes it different? How secure is Bitcoin? How anonymous are Bitcoin users? What applications can be built using Bitcoin as a platform? Can cryptocurrencies be regulated? What is the future of Bitcoin and cryptocurrencies in general? Prerequisite: CS 767 (Strictly enforced - if prerequisite is not met, seek the instructor's explicit permission before registering).

CS 898AU. Assistive Mobile Computing (3).
Covers various research topics in the broad area of mobile computing as it applies to assistive technologies. Assistive technology is an umbrella term that includes assistive, adaptive and rehabilitative devices for people with special needs, and also includes the process used in selecting, locating and using them. Students are exposed to several interdisciplinary research challenges in the design and application of mobile computing platforms when they are used as assistive technologies. These include intermittent network connectivity, battery and performance constraints, indoor localization and navigation, human computer interfaces, biomechanics and human factors. Each student is expected to acquire and apply technical skills to solve some of these research challenges working in groups to complete a research project at the end of the class. Students are also expected to read, present and critique existing research literature in the area. Prerequisites: CS 560, and prior experience creating mobile applications with Android or iOS.

CS 898AV. Software Defined Networking (3).
SDN has been widely envisioned to be the next-generation networking paradigm for both wired and wireless networks (e.g., Google B4 SDN data center networks and AT&T SDN cellular systems). Students are first introduced to SDN development history, SDN architectural design, SDN traffic engineering, and SDN development tools, (e.g., SDN management protocols Openflow and FlowVisor), network controllers (e.g., Floodlight and RYU), and software programmable switches (e.g., Open vSwitches). Then, students are instructed on how these technologies are applied to some emerging applications (e.g., data
center networks, cloud-computing environments, internet, and cellular systems). Finally, the group lab assignment is implemented on the OpenFlow-Mininet simulators as well as on a state-of-the-art wireless SDN testbed. Prerequisite: CS 764 or CS 835 or CS 898AF (Cognitive Radio Networks).

CS 898AW. Artificial Intelligence for Robotics (3).
Focuses on scene understanding, decision making and reasoning for robots, and action planning. Prerequisites: MATH 511, IME 254, CS 560.

CS 898AX. Foundations of Data Science (3).
Mathematical toolkit that can be applied to problems in data analysis. Topics covered: geometry of high dimensional space; best-fit subspaces and singular value decomposition (SVD); random walks and Markov chains; machine learning; algorithms for massive data problems: streaming, sketching and sampling; clustering. Prerequisites: CS 560, MATH 511.

CS 898AY. Sequential Decision Problems (3).
Sequential decision problems arise in many applications including packet routing, ad placement, website and page content optimization, or medium access in wireless communications. They typically involve a trade-off between exploration and exploitation, which corresponds to the decision of either exploiting an option that gave high rewards in the past or exploring new options with the hope to obtain higher rewards. Introduces learning methods for sequential decision problems, and presents their theoretical analyses. Topics covered include multi-armed bandits, stochastic bandits, adversarial bandits, Markov decision processes, tools for regret analysis. Prerequisite: EE 754 or CS 731.

CS 898AZ. Accessible Computing (3).
Covers various research topics in the area of accessible computing, defined as assistive, adaptive and rehabilitative computing devices, software and techniques for people with special needs to access and use various services. Students are exposed to several interdisciplinary research challenges in the design and application of mobile computing platforms when used towards the accessible computing paradigm. These include intermittent network connectivity, battery and performance constraints, indoor localization and navigation, human computer interfaces, biomechanics and human factors. Each student acquires and applies technical skills to solve research challenges working in groups to complete a research project at the end of the class. Students are also expected to read, present and critique existing research literature in the area. Students from non-CS backgrounds (such as psychology, bioengineering, kinesiology, exercise science, gerontology, communication sciences and disorders, among others) are welcome, and add a multidisciplinary flavor to the class. Students from non-CS backgrounds will have the curriculum adapted to their unique backgrounds. Prerequisites: For computer science (CS) and related majors: CS 560 or equivalent, and prior experience creating mobile applications with Android or iOS. For students with non-CS backgrounds: instructor’s consent.

CS 898B. Information Retrieval (3).
Course deals with information retrieval on the web. Roughly, it deals with how search engines select the desired documents, based on the query. Topics include Boolean retrieval, inverted indexes, and their construction; ranked retrieval, term weighting and relevance ranking. Prerequisite: CS 560.

CS 898CA. Introduction to Intelligent Robotics (3).
The study of intelligent robotics allows robots to gather information from surrounding environments and take actions autonomously. Course introduces the fundamental principles and methods of manipulation, navigation and perception for intelligent robotics. Topics covered include geometry transformations, kinematics, dynamics, localization, navigation, mapping, motion planning, intelligent processing, smart sensing, decision making and robotic intelligence. Students explore the robot concepts and algorithms, such as dexterous manipulation, simultaneous localization and mapping (SLAM), and autonomy, while working with Nao humanoid robots and Sawyer collaborative robots. Prerequisite: MATH 511.

CS 898CB. Deep Learning for Brain-Computer Interface (3).
Presents a framework on deep learning algorithms with a focus on brain-computer interface systems. A brain-computer interface system is a direct pathway between human brain and an external device. These systems present research avenues into understanding how the human brain works with the aim of helping people with physical disabilities. Students learn machine learning and deep learning concepts such as feature extraction and classification, and to apply those concepts to brain-computer interface problems.