

COMPUTER SCIENCE

College of Science and Engineering

Dean: Dr. Carmen Domingo

Department of Computer Science

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Chair: Arno Puder

Undergraduate Advisors: Dujmovic, Kulkarni, Wong, Yang, Yue

Graduate Coordinators: Yang

Graduate Advisors: Okada, Yoon

Program Scope

The primary mission of the Department of Computer Science is to prepare students for careers as software professionals and graduate studies in Computer Science and related fields. The department offers a broad curriculum covering the major areas of the computing discipline, integrated with soft skills such as teamwork and written/oral communication; students also gain experience working on group projects. Students are exposed to the fundamentals of computing architecture and computing theory, and focus their studies on the areas of software and systems development. Faculty work directly with students to help them develop the skills and knowledge of computing professionals.

Department faculty are committed to teaching excellence. They remain current in the rapidly changing field of computing technology through continuing research and publications, direct consultation with local industries, and seminar programs that bring top researchers and industry leaders to campus to speak on current developments in the field. The Supervised Industrial Research Program, Practicum option, and other mechanisms provide opportunities for graduate students to complement their academic learning with real-world experience.

The department has an additional commitment to sharing its knowledge and skills with the rest of the University community, with local schools, and with community-based organizations in the Bay Area.

The Bachelor of Science program stresses a basic foundation in mathematics and physics, and a thorough study of the fundamentals of the discipline: software development, computer architecture, operating systems, programming languages, algorithms, and the theoretical foundations of computer science. A wide variety of elective courses such as mobile development, web/internet applications, bioinformatics, database systems, artificial intelligence, computer graphics, game development, and software engineering allow students to specialize in selected areas. Ethical and social issues of computing are discussed throughout the curriculum. Senior courses include group projects to better prepare students for future job markets. Courses are updated or added regularly to provide necessary training in the latest software technologies.

The Master of Science in Computer Science prepares students for a wide variety of careers in computing or related industries as well as for advanced study toward Ph.D. degrees. Our program combines a solid and practical curriculum with high-quality research and project-based activities. In addition to a general core covering the breadth of

the computing discipline, students may focus on software engineering in globally distributed environments, computing applications for biotechnology and the life sciences, data mining/big data, and business applications.

Our faculty maintain active publication records, with significant funding from government agencies (NSF, NIH, Department of Labor, etc.) and industry (Genentech, Microsoft, IBM, Arista Networks, Mozilla, etc.). Students are actively involved in research projects, write papers, attend conferences, and participate in funding proposals. SF State's Center for Computing for Life Sciences (<http://cs.sfsu.edu/ccls/index.html>) and several specialized laboratories provide research and project focus, as well as opportunities to collaborate with faculty and students from other SF State departments and industry. A new Entrepreneurship Program and Developers Prize supports the development of student projects into business or non-profit ventures.

Computing Facilities

Central Facilities

- A network of Mac, Linux, and PC servers supported by SF State Information Technology Services
- A Linux server (unixlab) supported by SF State Information Technology Services, used for Computer Science classes
- Workstation labs in the SF State J. Paul Leonard Library and around campus

General Undergraduate Computing Facilities

- Intel servers (Windows and Linux)
- Workstation laboratories with Mac, Windows, and Linux desktops

Specialized Centers, Laboratories, and Computing Resources

- Center for Computing for Life Sciences (including Amazon cloud servers and 40-node DELL cluster)
- Multimedia and Visualization Laboratory
- Biocomputing and Media Research Group
- Biomedical Image and Data Analysis Lab
- Virtual Computing: VMware GSX Server, Microsoft VirtualPC Server
- High-Performance Computing server with NVIDIA Tesla and Titan GPUs

Career Alternatives

- Mobile application developer
- Web and internet application developer
- Game developer
- Bioinformatics Developer
- Data science/data mining developer
- Software Engineer
- Quality assurance engineer
- Manager of software development teams
- Systems programmer/administrator
- Computer network specialist
- System security and/or performance manager
- Application software designer
- Database designer/programmer/administrator
- Programmer in scientific or business applications

Professor

JOZO J. DUJMOVIC (1994), *Professor of Computer Science*; B.S. (1964), M.S. (1973), Ph.D. (1976), University of Belgrade, Yugoslavia.

WILLIAM TSUN-YUK HSU (1992), *Professor of Computer Science*; B.S. (1983), M.S. (1985), Purdue University; Ph.D. (1992), University of Illinois.

KAZUNORI OKADA (2006), *Professor of Computer Science*; B.E. (1992), Nagoya University, Japan; M.S. (1996), Ph.D. (2001), University Southern California.

DRAGUTIN PETKOVIC (2003), *Professor of Computer Science*; B.S. (1976), M.S. (1979), University of Belgrade, Yugoslavia; Ph.D. (1983), University of California, Irvine.

ARNO PUDER (2008), *Professor of Computer Science*; Diploma (1993), University of Kaiserslautern, Germany; Ph.D. (1997), University of Frankfurt, Germany

RAHUL SINGH (2004), *Professor of Computer Science*; M.S.E., Moscow Power Engineering Institute; M.S., Ph.D. (1999), University of Minnesota.

C. S. (JAMES) WONG (1990), *Professor of Computer Science*; B.S. (1984), University of Toronto; M.S. (1986), Southwest Texas State University; Ph.D. (1990), The University of Texas, Dallas.

ILMI YOON (2000), *Professor of Computer Science*; B.S. (1992), Yonsei University (Korea); M.S. (1966), Ph.D., (2000), University of Southern California.

Associate Professor

HUI YANG (2006), *Associate Professor of Computer Science*; B.S. (1993), Huazhong University, China; M.S. (2002), Ph.D. (2006), Ohio State University.

Assistant Professor

ABEER ALJARRAH (2018), *Assistant Professor of Computer Science*; B.Sc. (2005) Jordan University of Science and Technology, M.Sc. (2010), Yarmouk University; Ph.D. (2018), University of North Carolina at Charlotte.

POOYAN FAZLI (2018), *Assistant Professor of Computer Science*; B.Sc. (2003), M.Sc. (2006), Amirkabir University of Technology; Ph.D. (2013), Postdoctoral Fellow (2013-2014), University of British Columbia; Postdoctoral Research Fellow (2014-2015), Carnegie Mellon University.

ANAGHA K. KULKARNI (2013), *Assistant Professor of Computer Science*; B.E. (2001), University of Pune, India; M.S. (2006), University of Minnesota; Ph.D. (2013), Carnegie Mellon University.

HAO YUE (2015), *Assistant Professor of Computer Science*; B.Engr. (2009), Xidian University (China); Ph.D. (2015), University of Florida.

Adjunct Professor

JOHN HODGES (2000), *Adjunct Professor of Computer Science*; B.S. (1976), M.S. (1978), University of Michigan; Ph.D. (1993), University of California, Los Angeles.

Lecturers

Bhaskar,

Erwin, Esselmann, Gibson, Hasan, Jones, Kalinin, Kang, Kriese, Mehta, Mogos, Ortiz-Costa, Parra, Phyo, Pico, Pinera, Roberts, Scott, Sikder, Souza, Ta, Tomasevich, Tuttle

Major

- [Bachelor of Science in Computer Science](#)

Minor

- [Minor in Computer Science](#)
- [Minor in Computing Applications](#)

Masters

- [Master of Science in Computer Science](#)

Certificates

- [Graduate Certificate in Software Engineering](#)
- [Graduate Certificate in Ethical Artificial Intelligence](#)

CSC 101 Computers for Everyone (Units: 3)

Comprehensive and basic overview of computers and their use for everyday tasks such as information retrieval, Internet, writing, presentations, communication, Web publishing, e-commerce, entertainment, computation. No prior knowledge required.

CSC 110 Computational Thinking and Quantitative Reasoning (Units: 3)

Prerequisites: Category I or II placement for QR/Math, or satisfactory completion of ELM requirement, or MATH 70 or ESM 70 with a grade of C or better. Students with Category III or IV placement for QR/Math or students who have not passed MATH 70 or ESM 70 with a C or better must concurrently enroll in MATH 112.

Basic building blocks of programming and computational thinking practices including analyzing the effects of computation, creating computational artifacts, using abstractions and models, analyzing problems and artifacts, communicating processes and results, and working effectively in teams. Mathematical models and information retrieval from real-world datasets will be used as vehicles to practice programming and computation thinking.
(Note: For this course to satisfy General Education, students must earn a grade of C- or CR or higher.)

Course Attributes:

- B4: Math/QR

CSC 203 JAVA Programming (Units: 3)

Prerequisite: CSC 210 or consent of the instructor.

JAVA language and object-oriented programming. Use of inheritance, polymorphism, exception handling and libraries, and JAVA applets and GUI development using Swing.

CSC 206 Python Programming (Units: 3)

Prerequisite: CSC 210 or consent of the instructor.

Python language programming with basic principles of interpretative languages. The use of basic Python constructs and standard libraries (e.g., networking, regular expressions, GUI). Simple apps such as WWW and games.

CSC 208 C++ for Java Programmers (Unit: 1)

Prerequisites: Java programming courses or consent of the instructor.

Hands-on exercises in C++ programming. Emphasis on the features common to C++ and Java and features unique to C++. (CR/NC grading only)

CSC 210 Introduction to Computer Programming (Units: 3)

Prerequisite: Concurrent enrollment in CSC 211 required for Computer Science majors and recommended for non-majors.

Design, implementation, testing, debugging, maintenance, and documentation of Java programs. Algorithms, programming concepts, and data types in Java. Concepts of object-oriented programming. Numerical and non-numerical problems.

CSC 211 Introduction to Software Lab (Unit: 1)

Prerequisite: Concurrent enrollment in CSC 210.

Hands-on exercises in programming, and the use of basic software development tools. Covers procedural, object-oriented, C++, and JAVA programming. Students are encouraged to bring their laptops. Activity. May be repeated for a total of 3 units. (CR/NC grading only)

CSC 220 Data Structures (Units: 3)

Prerequisite: CSC 210 or CSC 309 or CSC 306 with a grade of C or better.

Linear and non-linear data structures in Java, including lists, stacks, queues, trees, tables, and graphs. Recursion, iteration over collections, sorting, searching, Big O notation, and hash tables.

CSC 230 Discrete Mathematical Structures for Computer Science (Units: 3)

Prerequisites: CSC 210 and MATH 227 (may be taken concurrently) with grades of C or better.

Review of set algebra, relations and functions, permutations, propositional logic, proof techniques, introduction to graph theory, and infinite sets, and their applications to computer science.

CSC 256 Machine Structures (Units: 3)

Prerequisite: CSC 230 with a grade of C or better.

Digital logic circuits, data representation, assembly language programming, subroutine linkage, machine language encoding, interrupt and exception handling, memory system concepts, and CPU organization and performance.

CSC 300GW Ethics, Communication, and Tools for Software Development - GVAR (Units: 3)

Prerequisites: Restricted to upper-division Computer Science majors and minors; GE Area A2; CSC 210.

Privacy, security, legal, and ethical issues in Software development. Communication relevant to SW development (e.g., reports, contracts, requirements, documentation, collaboration, e-mail, presentations). Study and use of basic tools for SW development and collaboration. (ABC/NC grading only)

Course Attributes:

- Graduation Writing Assessment

CSC 306 An Interdisciplinary Approach to Computer Programming (Units: 3)

Prerequisites: Restricted to Biology, Chemistry, and Biochemistry majors or pre-majors; upper-division standing; or consent of the instructor.

Basics of programming for interdisciplinary problem-solving. Topics include basic building blocks of programming (variable, control statement, iterative statement, array, function, and abstraction) and problem-solving approaches. Use of App Inventor and Java.

CSC 307 An Interdisciplinary Approach to Web Programming (Units: 3)

Prerequisite: Upper-division standing or consent of the instructor.

Basics of WWW engineering relevant to studies in interdisciplinary problem-solving. Topics include the basics of developing web and database applications, HTML, PHP, Python, SQL, and MySQL database.

CSC 309 Computer Programming for Scientists and Engineers (Units: 3)

Prerequisite: MATH 226 or consent of the instructor.

Procedural programming for scientific applications. Good programming practices and basic numerical and nonnumerical algorithms for scientists and engineers.

CSC 317 Introduction to Web Software Development (Units: 3)

Prerequisite: CSC 220 or consent of the instructor.

Introduction to topics in UNIX and creating web pages including reading and processing user input submitted through web pages, client side and server side programming, connecting a web page to a database, and building an e-commerce site or Internet Application.

CSC 340 Programming Methodology (Units: 3)

Prerequisites: CSC 220, CSC 230, and MATH 227 with grades of C or better.

Advanced data structures and algorithms for manipulation in C++ with an emphasis on design and implementation, practical applications, and algorithms for sorting, searching, and graphs.

CSC 412 Advanced Software Lab (Unit: 1)

Prerequisites: CSC 220; concurrent enrollment in CSC 340 recommended.

Hands-on exercises in advanced programming, software development tools, and web technologies. Students are encouraged to bring their laptops. Activity. May be repeated for a total of 2 units. (Plus-minus letter grade only)

CSC 413 Software Development (Units: 3)

Prerequisite: CSC 220 with grade of C or better.

Modern software applications. Object-oriented techniques: encapsulation, inheritance, and polymorphism as a mechanism for data design and problem solution. Software design, debugging, testing, and UI design. Software maintenance. Software development tools. Extra fee required. (Plus-minus letter grade only)

CSC 415 Operating System Principles (Units: 3)

Prerequisites: CSC 256, CSC 340*, MATH 324, and PHYS 230 with grades of C or better or graduate standing*.

Operating system concepts: concurrent processes, basic synchronization techniques, deadlock, memory management, file systems, security, networks, and distributed processing. Extra fee required.

CSC 510 Analysis of Algorithms I (Units: 3)

Prerequisites: CSC 340 and MATH 324 with grades of C or better.

Notions of main algorithm design methods. Measures of algorithm complexity in space and time. Algorithms of classic problems including sorting and scheduling and complexity analysis of such algorithms.

CSC 520 Theory of Computing (Units: 3)

Prerequisites: CSC 220, CSC 230, and MATH 325 with grades of C or better.

Automata, formal languages, and the notion of computability. Sequential machines as language acceptors. Context-free and context-sensitive grammars. Recursive functions and universal Turing machines. Unsolvable problems.

CSC 600 Programming Languages (Units: 3)

Prerequisites: CSC 413* and CSC 510 with grades of C or better or Graduate level standing.

Concepts for high-level programming languages. Procedural, logic, functional, and object-oriented programming paradigms. Comparative study of several languages and an introduction to grammars and parsing techniques. Extra fee required.

CSC 615 UNIX Programming (Units: 3)

Prerequisite: CSC 415 with a grade of C or better or consent of the instructor.

Programming in a UNIX environment. Topics include regular expressions, utilities such as awk, sed, grep, csh, sh, and ksh, system calls such as signals, sockets, POSIX IPC, and POSIX threads, and kernel internal structures. Extra fee required. (Plus-minus letter grade only)

CSC 620 Natural Language Technologies (Units: 3)

Prerequisite for CSC 820: Graduate standing or consent of the instructor. Prerequisites for CSC 620: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Natural language parsing technology and grammars. Elements of computational semantics, discourse structure, and generation. Survey of related topics such as information retrieval, question-answering, machine translation, and speech processing. Extra fee required. (Plus-minus letter grade only)

(CSC 820/CSC 620 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 621 Biomedical Imaging and Analysis (Units: 3)

Prerequisites for CSC 821: Graduate standing; CSC 510 and MATH 325 with grades of C or better; or consent of the instructor.

Prerequisites for CSC 621: Upper-division standing; CSC 510 and MATH 325 with grades of C or better; GPA of 3.0 or higher; or consent of the instructor.

Introduction to medical and biological imaging, imaging physics, 3D image formats, and visualization. Basic digital image processing and analysis, filtering, registration, segmentation, quantification, and performance evaluation. (Plus-minus letter grade only)

(CSC 821/CSC 621 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 630 Computer Graphics Systems Design (Units: 3)

Prerequisites: CSC 340 and MATH 325 with grades of C or better.

Graphics system design and display hardware architecture. Overview of device-independent graphic systems, 2- & 3-dimensional viewing pipelines, hidden line and surface removal algorithms, raster graphics techniques, and color space models. Webpage design and Flash exercises for an introduction to animation and multimedia. Course fee required. (Plus-minus letter grade only)

CSC 631 Multiplayer Game Development (Units: 3)

Prerequisite for CSC 831: Graduate standing or consent of the instructor. Prerequisites for CSC 631: Upper-division standing; CSC 413; GPA of 3.0 or higher; or consent of the instructor.

Computer graphics and network characteristics of multiplayer games. Design and development of a game as a team project. (CSC 831/CSC 631 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 637 Software Techniques for Computer Music (Units: 3)

Prerequisite: CSC 413 with a grade of C or better or consent of the instructor.

Algorithms and software design for digital audio and computer music. Analysis and synthesis techniques. Real-time control and interaction. Extra fee required.

CSC 641 Computer Performance Evaluation (Units: 3)

Prerequisite for CSC 841: Graduate standing or consent of the instructor. Prerequisites for CSC 641: Upper-division standing; CSC 415; GPA of 3.0 or higher; or consent of the instructor.

Computer performance analysis problems related to system design, selection, and tuning. Modeling using stochastic and operational queuing models. Workload characterization, design, and performance measurement methods. Design of simulation models for computer systems. Extra fee required. (Plus-minus letter grade only) (CSC 841/CSC 641 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 642 Human-Computer Interaction (Units: 3)

Prerequisite: CSC 413 with a grade of C or better or consent of the instructor.

The design, implementation, and evaluation of human-computer interfaces. Topics include interface devices, interface metaphors, interaction styles, user-centered design, testing, and quality assessment. Extra fee required.

CSC 644 Computer Measurements (Units: 3)

Prerequisites: CSC 413 and CSC 415.

Software measurement and experimentation tools. Data collection and analysis. Web measurements. Benchmarking and design of benchmarks. Use of software monitors. Extra fee required. (Plus-minus letter grade only)

CSC 645 Computer Networks (Units: 3)

Prerequisites: Upper-division standing; CSC 415 with a grade of C or better; GPA of 3.0 or better; or consent of the instructor.

Computer network design, evaluation, and testing. Computer network standards and implementation. Hardware and software design and compatibility issues. Extra fee required.

CSC 648 Software Engineering (Units: 3)

Prerequisite for CSC 848: Graduate standing or consent of the instructor.
Prerequisites for CSC 648: Upper-division standing; CSC 413* with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Practical methods and tools for SW engineering including organizational teamwork.

(CSC 848/CSC 648 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 650 Secure Networked Systems (Units: 3)

Prerequisites: CSC 415 with a grade of C or better or consent of the instructor.

Analysis, planning, construction, and operation of secure networked computing systems including security for environments within Internet, encryption, assets, risk, authentication, trust, controls, defense, routers, firewalls, law, and ethics. Extra fee required.

CSC 651 System Administration (Units: 3)

Prerequisites: CSC 413 and CSC 415 with grades of C or better.

User administration. Operating system installation, tuning, and control. Network administration. Security management. Performance tuning and management. Extra fee required. (ABC/NC grading only)

CSC 656 Computer Organization (Units: 3)

Prerequisite: CSC 415 (may be taken concurrently) or consent of the instructor.

Instruction set design. Pipelined datapath and control. Cache and memory system design. Input and output subsystems. Parallel processing. Software and hardware interactions. Extra fee required.

CSC 658 Programming Cafe (Units: 3)

Prerequisite: CSC 413 with a grade C or better or consent of the instructor.

Extensive programming practice to advance programming skills and processes including pair programming exercises and code review techniques and practice.

CSC 664 Multimedia Systems (Units: 3)

Prerequisite for CSC 864: Graduate standing or consent of the instructor.
Prerequisites for CSC 664: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Comprehensive topics in multimedia such as basics of image and video processing, compression, multimedia databases, standard, synchronization, formats in perspective of systems, and algorithms. Extra fee required. (Plus-minus letter grade only)

(CSC 864/CSC 664 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 665 Artificial Intelligence (Units: 3)

Prerequisite: CSC 413 with a grade of C or better.

Overview of algorithms and approaches central to artificial intelligence. Study of fundamental concepts needed to attain human-level intelligence in computer systems, and gain experience in working with these concepts through assignments and programming exercises. Topics include problem-solving methods, heuristic search, game playing; agent architectures; machine learning; and various topics selected from knowledge representation, symbolic reasoning, computational models of virtual humans, neural networks, and genetic algorithms. Learn how to research, assess, and review advances in the field, and to consider the application of artificial intelligence techniques to real-world problems. Extra fee required.

CSC 667 Internet Application Design and Development (Units: 3)

Prerequisite for CSC 867: Graduate standing or consent of the instructor.
Prerequisites for CSC 667: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Fundamental technologies on which the World Wide Web is based. Extra fee required.

(CSC 867/CSC 667 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 668 Advanced Object Oriented Software Design and Development (Units: 3)

Prerequisite for CSC 868: Graduate standing or consent of the instructor.
Prerequisites for CSC 668: Senior standing; CSC 413 with a grade of C or better; GPA of 3.0 or better; or consent of the instructor.

Object-oriented analysis and design utilizing UML, design patterns, frameworks, and toolkits. Agile software design processes. Development of a mid-size programming project working in teams. (Plus-minus letter grade only)

(CSC 868/CSC 668 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 671 Neural Networks (Units: 3)

Prerequisite for CSC 871: Graduate standing or consent of the instructor.
Prerequisites for CSC 671: Upper-division standing; CSC 510 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Artificial neural networks including associative memories, learning, search, databases, fuzzy set techniques, pattern recognition, and adaptive processing.

(CSC 871/CSC 671 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 675 Introduction to Database Systems (Units: 3)

Prerequisite for CSC 775: Graduate standing or consent of the instructor.
Prerequisites for CSC 675: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Relational query languages. Semantic data models. Logical and physical database design. Privacy issues. Implementation techniques (catalogs, query optimization, concurrency control, security, and integrity enforcement). Extra fee required.

(CSC 775/CSC 675 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 690 Interactive Multimedia Application Development (Units: 3)

Prerequisite: CSC 340 with a grade of C or better or consent of the instructor.

Basics of multimedia data formats and algorithms to build applications using non-standard interfaces such as game controllers and multi-touch surfaces. (Plus-minus letter grade only)

CSC 693 Cooperative Education Program (Units: 6-12)

Prerequisite: Upper-division standing or consent of the instructor.

Units do not count toward the major. May be repeated for a total of 24 units. Contact the Cooperative Education office for information. (CR/NC grading only)

CSC 694 Cooperative Education: Computer Science (Units: 1-3)

Prerequisite: Consent of the instructor.

Projects in a business, government, or industrial position of at least one semester's duration. May be repeated for a total of 3 units.

CSC 695 Computing in the Community (Units: 2)

Prerequisites: Upper-division standing; computer experience; consent of the instructor.

Extensive fieldwork training Bay Area non-profit agencies in the use of computer tools such as conferencing and database systems. Development of user documentation. (CR/NC grading only)

CSC 697 Senior Project in Computer Science (Units: 3)

Prerequisites: CSC 415 and CSC 510, or CSC 648; or consent of the instructor.

Culminating experience in individual design, implementation, and professional documentation of a software product under the close supervision of a faculty member. (Plus-minus letter grade only)

CSC 698 Topics in Computing (Units: 3)

Prerequisite: Upper-division standing or consent of the instructor.

Current topics in computer hardware and software technologies. Topics to be specified in the Class Schedule. May be repeated for a total of 9 units when topics vary.

CSC 699 Independent Study (Units: 1-3)

Prerequisites: Consent of the department and instructor. An approved study proposal must be on file by the time of registration.

Library and laboratory research and development projects. A final report must be approved by the instructor and filed with the department. May be repeated for a total of 9 units. (Plus-minus letter grade only)

CSC 720 Advanced Operating Systems (Units: 3)

Prerequisites: Satisfaction of Written English Proficiency Level I or concurrent enrollment in SCI 614; CSC 415 with a grade of B or better; or consent of the instructor.

Analysis of scheduling and memory management algorithms and the use of concurrent languages for systems development and distributed systems. Design and implementation of major components of an operating system. Extra fee required.

CSC 730 Advanced Database Systems (Units: 3)

Prerequisites: CSC 413 and CSC 675 with grades of C or better.

Standard SQL, query optimization, concurrency control, crash recovery, authorization, and integrity enforcement. Object-oriented, extensible, deductive, and distributed database systems. Extra fee required.

CSC 746 High-Performance Computing (Units: 3)

Prerequisite: CSC 656 with a grade of B or better or consent of the instructor.

Principles and current practices in high-performance computing. Basics of multiprocessor systems such as clusters and graphics processors. Message-passing and shared memory-based software development. Cloud computing.

CSC 775 Introduction to Database Systems (Units: 3)

Prerequisite for CSC 775: Graduate standing or consent of the instructor. Prerequisites for CSC 675: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Relational query languages. Semantic data models. Logical and physical database design. Privacy issues. Implementation techniques (catalogs, query optimization, concurrency control, security, and integrity enforcement). Extra fee required.

(CSC 775/CSC 675 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 780 Application Development for Mobile Devices (Units: 3)

Prerequisite: Restricted to senior and graduate Computer Science students; CSC 415 with a grade of B or better; or consent of the instructor.

Introduction to and comparison of different popular mobile application frameworks. Conceptual and hands-on experience in writing mobile applications using native and cross-platform tools. (Plus-minus letter grade only)

CSC 810 Analysis of Algorithms II (Units: 3)

Prerequisites: Passing GET score or concurrent enrollment in SCI 614; CSC 510 with a grade of B or better.

Review major design strategies and theory of NP-Completeness. Approximation algorithms. Online Algorithms. Parallel and distributed algorithms. Algorithms for specific areas of interest. Extra fee required.

CSC 820 Natural Language Technologies (Units: 3)

Prerequisite for CSC 820: Graduate standing or consent of the instructor. Prerequisites for CSC 620: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Natural language parsing technology and grammars. Elements of computational semantics, discourse structure, and generation. Survey of related topics such as information retrieval, question-answering, machine translation, and speech processing. Extra fee required. (Plus-minus letter grade only)

(CSC 820/CSC 620 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 821 Biomedical Imaging and Analysis (Units: 3)

Prerequisites for CSC 821: Graduate standing; CSC 510 and MATH 325 with grades of C or better; or consent of the instructor. Prerequisites for CSC 621: Upper-division standing; CSC 510 and MATH 325 with grades of C or better; GPA of 3.0 or higher; or consent of the instructor.

Introduction to medical and biological imaging, imaging physics, 3D image formats, and visualization. Basic digital image processing and analysis, filtering, registration, segmentation, quantification, and performance evaluation. (Plus-minus letter grade only) (CSC 821/CSC 621 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 825 Advanced Automata Theory (Units: 3)

Prerequisite: CSC 520 or equivalent.

Advanced topics in theoretical computer science and their application to a broad range of areas including bioinformatics, compilers, data and image compression, natural language processing, networking, and web applications. Extra fee required. (Plus-minus letter grade only)

CSC 830 Advanced Computer Graphics (Units: 3)

Prerequisite: CSC 630 or consent of the instructor.

Raster graphics principles and scanning algorithms, pixel fill algorithms, anti-aliasing, clipping, hidden line and surface display, rendering of surfaces, and fractal techniques. Extra fee required.

CSC 831 Multiplayer Game Development (Units: 3)

Prerequisite for CSC 831: Graduate standing or consent of the instructor. Prerequisites for CSC 631: Upper-division standing; CSC 413; GPA of 3.0 or higher; or consent of the instructor.

Computer graphics and network characteristics of multiplayer games. Design and development of a game as a team project. (CSC 831/CSC 631 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 835 Distributed Systems (Units: 3)

Prerequisite: CSC 415 with a grade of B or better or consent of the instructor.

Introduction to the concepts and design of distributed systems. Includes a term project in using current middleware technologies. Extra fee required.

CSC 837 Advanced Sound Synthesis (Units: 3)

Prerequisite: CSC 637 with a grade of B or better or consent of the instructor.

Current algorithms and practices in sound synthesis and timbral control for music, sound effects, and interactive environments. Design of real-time software synthesis systems. Extra fee required.

CSC 840 Software Metrics and Quality Assurance (Units: 3)

Prerequisite: CSC 648 or consent of the instructor.

Measurement and modeling in software engineering. Software performance evaluation methods. Techniques and tools for software quality assurance. Software quality standards. Design and use of software metrics tools. Extra fee required. (Plus-minus letter grade only)

CSC 841 Computer Performance Evaluation (Units: 3)

Prerequisite for CSC 841: Graduate standing or consent of the instructor. Prerequisites for CSC 641: Upper-division standing; CSC 415; GPA of 3.0 or higher; or consent of the instructor.

Computer performance analysis problems related to system design, selection, and tuning. Modeling using stochastic and operational queuing models. Workload characterization, design, and performance measurement methods. Design of simulation models for computer systems. Extra fee required. (Plus-minus letter grade only) (CSC 841/CSC 641 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 842 Advanced Human-Computer Interaction (Units: 3)

Prerequisite: Graduate standing.

Design, implementation, and evaluation of human/computer interfaces. Topics include those covered in CSC 642 - interface devices, interface metaphors, interaction styles, user-centered design, testing, and quality assessment; however, an emphasis is placed on human-computer interaction with respect to culminating experience work. Extra fee required. (Plus-minus letter grade only)

CSC 845 Advanced Computer Networks (Units: 3)

Prerequisites: CSC 415 and CSC 645; or consent of the instructor.

Design and implementation of networking protocols and technologies in wireless and mobile networks. Introduction to emerging design, algorithms, protocols, and applications in wireless and mobile networks. Extra fee required.

CSC 846 Systems Architecture (Units: 3)

Prerequisite: CSC 656 with a grade of B or better or consent of the instructor.

Principles of computer systems architecture with an emphasis on hardware and software interactions for large applications and design for performance. Extra fee required. (Plus-minus letter grade only)

CSC 847 Cloud and Distributed Computing: Concepts and Applications (Units: 3)

Prerequisites: Restricted to senior and graduate Computer Science students; CSC 415* with a grade of C or better; or consent of the instructor.

Infrastructure, platform, and software as a service. Includes enabling techniques behind cloud computing including virtualization, multi-tenancy, and service-oriented architecture. Cloud storage options such as NoSQL databases, emerging technologies such as containers and Kubernetes, parallel and distributed computing platforms including MapReduce and Apache Sparc, and hands-on experience on public clouds such as the Amazon Cloud and Google Cloud. (Plus-minus letter grade only)

CSC 848 Software Engineering (Units: 3)

Prerequisite for CSC 848: Graduate standing or consent of the instructor. Prerequisites for CSC 648: Upper-division standing; CSC 413* with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Practical methods and tools for SW engineering including organizational teamwork. (CSC 848/CSC 648 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 849 Search Engines (Units: 3)

Prerequisite: CSC 413 or consent of the instructor.

Introduction to the internals of modern search engines. Methods and tools for representation, storage, and organization of, and access to, textual data. Extra fee required. (Plus-minus letter grade only)

CSC 850 Compiler Design (Units: 3)

Prerequisites: CSC 413 with a grade of B or better; consent of the instructor.

Design and implementation of compilers including lexical scanners, top down and bottom up parsers, precedence grammars, symbol table manipulation, LR (k) grammars, semantics routines, and code generators.

CSC 856 Advanced Computer Architecture (Units: 3)

Prerequisites: Satisfaction of Written English Proficiency Level I or concurrent enrollment in SCI 614; CSC 656 with a grade of B or better; or consent of the instructor.

Advanced pipelining. Instruction-level parallelism. Advanced memory system design. Compiler techniques for performance. New technologies and applications. Extra fee required.

CSC 857 Bioinformatics Computing (Units: 3)

Prerequisites: Graduate standing in a science program; CSC 858; or consent of the instructor.

A broad range of topics in computational biology as practiced in the life science industry and leading research organizations. Provides computational background required to participate in R&D. Extra fee required.

CSC 858 Foundations of Biotechnology and Life Sciences (Units: 3)

Prerequisite: Graduate standing in a science program; a background in life sciences or biology is not required.

Foundations in biotechnology and life sciences. Prepare for further study and careers in biotechnology and computational life sciences R&D and industry.

CSC 859 AI Explainability and Ethics (Units: 3)

Prerequisite: CSC 865* or CSC 869* or CSC 872* or CSC 876* or consent of the instructor.

The impact of Artificial Intelligence on society and business. The need for explainable and ethical AI systems and related problems in current AI applications. Analysis and evaluation of technologies and methods for the design, development, evaluation, and deployment of explainable and ethical AI systems. (Plus-minus letter grade, RP only)

CSC 864 Multimedia Systems (Units: 3)

Prerequisite for CSC 864: Graduate standing or consent of the instructor. Prerequisites for CSC 664: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Comprehensive topics in multimedia such as basics of image and video processing, compression, multimedia databases, standard, synchronization, formats in perspective of systems, and algorithms. Extra fee required. (Plus-minus letter grade only)

(CSC 864/CSC 664 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 867 Internet Application Design and Development (Units: 3)

Prerequisite for CSC 867: Graduate standing or consent of the instructor. Prerequisites for CSC 667: Upper-division standing; CSC 413 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Fundamental technologies on which the World Wide Web is based. Extra fee required.

(CSC 867/CSC 667 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 868 Advanced Object Oriented Software Design and Development (Units: 3)

Prerequisite for CSC 868: Graduate standing or consent of the instructor. Prerequisites for CSC 668: Senior standing; CSC 413 with a grade of C or better; GPA of 3.0 or better; or consent of the instructor.

Object-oriented analysis and design utilizing UML, design patterns, frameworks, and toolkits. Agile software design processes. Development of a mid-size programming project working in teams. (Plus-minus letter grade only)

(CSC 868/CSC 668 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 869 Data Mining (Units: 3)

Prerequisites: CSC 510 and CSC 675 with grades of C or better; or consent of instructor.

Knowledge discovery process, basic data mining concepts, key mining algorithms, and data mining in practical domains such as bioinformatics. (Plus-minus letter grade only)

CSC 870 Computational Discrete Geometry (Units: 3)

Prerequisites: CSC 210, CSC 230, and MATH 325; or consent of instructor.

A comprehensive overview of basic topics in computational discrete geometry including generating functions, complexity theory, convex hull, nearest-neighbor problems, and efficient algorithms.

(This course is offered as MATH 870 and CSC 870. Students may not repeat the course under an alternate prefix.)

CSC 871 Neural Networks (Units: 3)

Prerequisite for CSC 871: Graduate standing or consent of the instructor. Prerequisites for CSC 671: Upper-division standing; CSC 510 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Artificial neural networks including associative memories, learning, search, databases, fuzzy set techniques, pattern recognition, and adaptive processing.

(CSC 871/CSC 671 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

CSC 872 Pattern Analysis and Machine Intelligence (Units: 3)

Prerequisites: CSC 510 and CSC 520 with grades of C or better; or consent of the instructor.

Foundation of pattern analysis and machine intelligence. Artificial intelligence: agent, logic, and search. Machine learning: Bayesian classification. Neural network: simulated annealing. Imaging: image segmentation and object recognition. (Plus-minus letter grade only)

CSC 874 Topics in Big Data Analysis (Units: 3)

Prerequisites: Graduate standing; CSC 510 or equivalent; or consent of the instructor.

Introduction to current topics in data sciences and big data analysis. (Plus-minus letter grade only)

CSC 875 Advanced Topics in Database Systems (Units: 3)

Prerequisite: CSC 675 with a grade of C or better.

Advanced aspects of selected topics in database systems. Topics depend on availability of staff and facilities. May be repeated for a total of 6 units when topics vary.

CSC 876 Soft Computing and Decision Support Systems (Units: 3)

Prerequisite: CSC 810 or consent of the instructor.

Survey of computational intelligence. Fuzzy sets, fuzzy logic, and fuzzy systems. Approximate reasoning. Possibility theory. Fuzzy decision making. Fuzzy controllers. Concept of rough sets. Computing with words, perceptual computing, and granular computing. Graded evaluation logic. Study of logic aggregation operators and information fusion models. Decision engineering methods. LSP method for evaluation and optimization of complex systems. Applications of soft computing. Development of software systems for decision support. (Plus-minus letter grade only)

CSC 890 Graduate Seminar (Units: 3)

Prerequisite: Consent of the instructor or graduate adviser.

Topics to be specified in the Class Schedule. May be repeated for a total of 6 units when topics vary. (Plus-minus letter grade only)

CSC 893 Supervised Industrial Research (Unit: 1)

Prerequisite: Consent of the instructor.

Supervised computer science employment in software research and development. Objectives are career development and occupational experience. May be repeated for a total of 3 units. Subsequently, may be repeated on CR/NC basis. Must be approved by a graduate adviser. (Plus-minus letter grade, CR/NC, RP)

CSC 895 Applied Research Project (Units: 3)

Prerequisites: Consent of the instructor and approval of Advancement to Candidacy (ATC) for the MS in CS and Culminating Experience (CE) forms by Graduate Studies. Advancement to candidacy and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration.

(CR/NC grading only)

CSC 897 Research (Units: 3-6)

Prerequisite: Consent of Computer Science Department.

Independent and original investigation under supervision of a faculty member. May be repeated for a total of 6 units. (Plus-minus letter grade, CR/NC, RP)

CSC 898 Master's Thesis (Units: 3)

Prerequisites: Consent of the instructor and graduate adviser and approval of Advancement to Candidacy (ATC) for the Master of Science in Computer Science and Culminating Experience (CE) forms by Graduate Studies. Advancement to Candidacy (ATC) and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration.

(CR/NC grading only)

CSC 899 Independent Study (Units: 1-3)

Prerequisite: Approval of the department and instructor.

Special study of a particular problem under the direction of a faculty member. The student must present a written, detailed report of the work accomplished to the staff of the department. May be repeated for a total of 6 units. (AB/NC only)