

# COMPUTER SCIENCE

<http://www.cs.iastate.edu>

The undergraduate curriculum in Computer Science leading to the Bachelor of Science degree is accredited by the Computing Accreditation Commission of ABET, <http://www.abet.org>. This degree equips students with a sound knowledge of the foundations of Computer Science as well as problem solving and system design skills necessary to create robust, efficient, reliable, scalable, and flexible software systems. The B.S. degree in Computer Science prepares students for graduate study in Computer Science and for various business, industry, and government positions including computer scientists, information technologists, and software developers. The main educational objectives of the Computer Science program at Iowa State University are that its graduates demonstrate expertise, engagement, and learning within three to five years after graduation.

•**Expertise:** Graduated students should have the ability to establish peer-recognized expertise in the discipline. They should have the ability to articulate this expertise by formulating and solving problems of interest, by creating or deriving value through the application of technology, and by using mathematical foundations, algorithmic principles, and computer science theory in designing, implementing, and evaluating computer-based systems and processes which meet the desired needs of their employers.

•**Engagement:** Graduated students should have the ability to be engaged in the profession through the practice of computer science in industry, academia, or the public sector. They should demonstrate effective teaming and commitment to working with others by applying communications skills and professional knowledge.

•**Learning:** Graduated students should have the ability to engage in sustained learning through graduate work, professional improvement opportunities, and self study so that they can adapt to the role played by information processing in ever-changing areas of science, technology, and society.

## Curriculum in Computer Science

A student seeking a B.S. degree in Computer Science must satisfy the requirements of the University and College of Liberal Arts and Sciences (see Liberal Arts and Sciences, Curriculum) and the departmental requirements.

The departmental requirements consist of a minimum of 46 credits in Computer Science and satisfaction of written and oral requirements. Students must earn at least a C- in Math 165, Math 166, and each Computer Science course taken to fulfill the Degree Program. The LAS College requires the major must contain at least 8

credits in courses taken at Iowa State University that are numbered 300 or above and in which the student's grade is C or higher.

The following courses are required:

COM S 101	Orientation	R
COM S 203	Careers in Computer Science	R
COM S 227	Object-oriented Programming	4
COM S 228	Introduction to Data Structures	3
COM S 309	Software Development Practices	3
COM S 311	Introduction to the Design and Analysis of Algorithms	3
COM S 321	Introduction to Computer Architecture and Machine-Level Programming	3
COM S 327	Advanced Programming Techniques	3
COM S 331	Theory of Computing	3
COM S 342	Principles of Programming Languages	3
COM S 352	Introduction to Operating Systems	3
COM S 402	Computer Science Senior Project	3

At least 15 credits, including at least 6 credits of 400-level courses, all with a grade of C- or better, from the following:

COM S 319	Construction of User Interfaces	3
COM S 336	Introduction to Computer Graphics	3
COM S 362	Object-Oriented Analysis and Design	3
COM S 363	Introduction to Database Management Systems	3
COM S 409	Software Requirements Engineering	3
COM S 410	Distributed Development of Software	3
COM S 412	Formal Methods in Software Engineering	3
COM S 415	Software System Safety	3
COM S 417	Software Testing	3
COM S 418	Introduction to Computational Geometry	3
COM S 421	Logic for Mathematics and Computer Science	3
COM S 424	Introduction to High Performance Computing	3
COM S 425	High Performance Computing for Scientific and Engineering Applications	3
COM S 426	Introduction to Parallel Algorithms and Programming	4
COM S 430	Concurrent Programming in Practice	3
COM S 433	Molecular Programming of Nanoscale Devices and Processes	3
COM S 435	Algorithms for Large Data Sets: Theory and Practice	3
COM S 437	Computer Game and Media Programming	3
COM S 440	Principles and Practice of Compiling	3
COM S 441	Programming Languages	3

COM S 444	Bioinformatic Analysis	4	BIOL 212	Principles of Biology II	4
COM S 454	Distributed Systems	3	& 212L	and Principles of Biology Laboratory II	
COM S 455	Simulation: Algorithms and Implementation	3	BIOL 255	Fundamentals of Human Anatomy	4
COM S 461	Principles and Internals of Database Systems	3	& 255L	and Fundamentals of Human Anatomy Laboratory	
COM S 472	Principles of Artificial Intelligence	3	BIOL 256	Fundamentals of Human Physiology	4
COM S 474	Introduction to Machine Learning	3	& 256L	and Fundamentals of Human Physiology Laboratory	
COM S 477	Problem Solving Techniques for Applied Computer Science	3	CHEM 177	General Chemistry I	5
COM S 481	Numerical Methods for Differential Equations	3	& 177L	and Laboratory in General Chemistry I	
COM S 486	Fundamental Concepts in Computer Networking	3	CHEM 178	General Chemistry II	4
COM S 487	Network Programming, Applications, and Research Issues	3	& 178L	and Laboratory in College Chemistry II	
CPR E 431	Basics of Information System Security	3	GEOL 100	How the Earth Works	4
CPR E 458	Real Time Systems	3	& 100L	and How the Earth Works: Laboratory	
CPR E 489	Computer Networking and Data Communications	4	GEOL 102	History of the Earth	4
			& 102L	and History of the Earth: Laboratory	
			PHYS 221	Introduction to Classical Physics I	5
			or PHYS 241	Principles and Symmetries in Classical Physics I	
			PHYS 222	Introduction to Classical Physics II	5
			or PHYS 242	Principles and Symmetries in Classical Physics II	

Com S 414 **may not** be applied towards fulfilling the 400-level electives.

Toward satisfying requirements of the College of Liberal Arts and Sciences, the following courses should be included:

PHIL 343	Philosophy of Technology	3
SP CM 212	Fundamentals of Public Speaking	3
At least 17 credits of Math and Statistics		17
MATH 165	Calculus I	4
MATH 166	Calculus II	4
COM S 230	Discrete Computational Structures	3
One Statistics course from:		
STAT 305	Engineering Statistics	3
STAT 330	Probability and Statistics for Computer Science	3
STAT 341	Introduction to the Theory of Probability and Statistics I	4
At least one Math course from:		
MATH 207	Matrices and Linear Algebra	3
MATH 265	Calculus III	4
MATH 266	Elementary Differential Equations	3
MATH 267	Elementary Differential Equations and Laplace Transforms	4
MATH 304	Combinatorics	3
MATH 314	Graph Theory	3
MATH 317	Theory of Linear Algebra	4
One of the following 2-course Natural Science sequences (with labs):		
BIOL 211	Principles of Biology I	4
& 211L	and Principles of Biology Laboratory I	

The following courses meet the communication proficiency requirement:

LIB 160	Information Literacy	1
ENGL 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
One of the following		
ENGL 302	Business Communication	3
ENGL 305	Creative Writing: Nonfiction	3
ENGL 309	Proposal and Report Writing	3
ENGL 314	Technical Communication	3

According to the university-wide Communication Proficiency Grade Requirement, students must demonstrate their communication proficiency by earning a grade of C or better in ENGL 250. The Department requires a C or higher in the upper-level ENGL course (302, 305, 309, 314).

To obtain a bachelor's degree from the College of Liberal Arts and Sciences, curriculum in liberal arts and sciences, a student must earn at least 45 credits at the 300 level or above taken at a four-year college. All such credits, including courses taken on a pass/not pass basis, may be used to meet this requirement.

Students must take at least 15 credits of Computer Science courses at the 300 level or higher at Iowa State University while resident here. Computer Science transfer courses need to be a minimum grade of C or higher to be considered for course substitution.

Students must earn a C- or better in each Computer Science course which is a prerequisite to a course listed in the student's degree program.

### Undergraduate Minor in Computer Science

The Department of Computer Science offers an undergraduate minor in Computer Science. The minor requires at least 16 credits in computer science courses. Com S 414 cannot be used to fulfill minor requirements.

A minimum grade of C- is required in Com S 227 and Com S 228. A minimum grade of C is required in both Com S 311 and the three credits of 300-level Computer Science courses and above. At least 6 credits of the minor must be in courses numbered 300 and above and taken at ISU with a grade of C or higher. The minor must include at least 9 credits that are not used to meet any other department, college, or university requirement.

COM S 227	Object-oriented Programming	4
COM S 228	Introduction to Data Structures	3
COM S 230	Discrete Computational Structures	3
COM S 311	Introduction to the Design and Analysis of Algorithms	3
3 credits in ComS courses at the 300 level or above		3

### Undergraduate Curriculum in Software Engineering

The Department of Computer Science, together with the Department of Electrical and Computer Engineering, also offer a curriculum leading to an undergraduate degree in Software Engineering. The Software Engineering curriculum offers emphasis areas in Software Engineering principles, process, and practice. Students may also take elective courses in Computer Engineering and Computer Science.

See Index, Software Engineering. For curriculum information, see also College of Engineering and College of Liberal Arts and Sciences.

## Computer Science, B.S.

### Freshman

Fall	Credits Spring	Credits
COM S 101	0 COM S 228	3
COM S 227	4 COM S 230	3
MATH 165	4 MATH 166	4
ENGL 150	3 Social Science	3
LIB 160	1 Foreign Language 102/ Elective	3-4
Foreign Language 101/ Elective	3-4	
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15-16		16-17

### Sophomore

Fall	Credits Spring	Credits
COM S 203	0 COM S 321	3
COM S 311	3 COM S 331	3
COM S 327	3 STAT 300-level elective	3
ENGL 250	3 Social science	3
Natural Science 1	5 Natural Science 2	5
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14		17

### Junior

Fall	Credits Spring	Credits
COM S 309	3 COM S 352	3
COM S 342	3 COM S 300-level elective	3
COM S 300-level elective	3 ENGL 300-level Elective	3
MATH elective	3-4 Arts and Humanities	3
SP CM 212	3 Elective	3
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15-16		15

### Senior

Fall	Credits Spring	Credits
COM S 300-level Elective	3 COM S 402	3
COM S 400-level Elective	3 COM S 400-level Elective	3
PHIL 343	3 Arts and Humanities	3
Arts and Humanities	3 Social Science	3
Elective	3 Elective	3
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15		15

## Graduate Study

The department offers graduate programs leading to degrees of Master of Science (MS) and Doctor of Philosophy (PhD) with a major in Computer Science. The Doctor of Philosophy degree may also be earned with computer science as a co-major with some other discipline. Additionally, the department offers a minor for the students majoring in other disciplines.

Established research areas include algorithms, artificial intelligence, computational complexity, computer architecture, bioinformatics, computational biology, computer networks, database systems, formal methods, information assurance, machine learning and neural networks, multimedia, operating systems, parallel and distributed computing, programming languages, robotics, and software engineering. There are also numerous opportunities for interdisciplinary research.

Typically, students beginning graduate work in Computer Science have completed a bachelor's degree or equivalent in Computer Science.

However, some students with undergraduate majors in other areas, such

as Mathematical, physical, or biological science or engineering become successful graduate students in Computer Science.

For the degree Master of Science, a minimum of 31 semester credits is required. A thesis or a creative component demonstrating research and the ability to organize and express significant ideas in computer science is required.

The purpose of the doctoral program is to train students to do original research in Computer Science. Each student is also required to attain knowledge and proficiency commensurate with a leadership role in the field. The PhD requirements are governed by the student's program of study committee within established guidelines of the department and the graduate college. They include coursework (demonstrating breadth and depth of knowledge), a research skills requirement, a preliminary examination, and a doctoral dissertation and final oral examination.

The department recommends that all graduate students majoring in Computer Science teach as part of their training for an advanced degree.

#### **Courses primarily for undergraduates:**

##### **COM S 101: Orientation**

Cr. R. F.S.

Introduction to the computer science discipline and code of ethics, Com S courses, research and networking opportunities, procedures, policies, help and computing resources, extra-curricular activities offered by the Department of Computer Science and Iowa State University. Discussion of issues relevant to student adjustment to college life. Offered on a satisfactory-fail basis only. Offered on a satisfactory-fail basis only.

##### **COM S 103: Computer Literacy and Applications**

Cr. 4. F.S.SS.

Introduction to computer literacy and applications. Literacy: Impact of computer technology in today's societies, hardware, software, software programming, database and information systems, communication and networks, digital media technology, computer security and safety, ethics and privacy. Applications: In-depth hands-on experience with the operating systems, Microsoft word processing, spreadsheets, database management and presentation software. No prior computer experience necessary. Offered online only. Attendance required at an orientation session the first week of class.

##### **COM S 104: Brief Introduction to Computer Programming for Non-Majors** (1.5-1) Cr. 2. F.S.

Offered first 8 weeks and last 8 weeks. Use of personal computer and workstation operating systems and beginning programming. Project-oriented approach to computer operation and programming, including use of tools to aid in programming. Topics from computer history, using basic Windows and Unix tools, program structure, expression, variables, decision and logic, and iteration. No prior computer experience necessary.

##### **COM S 105: Short Course in Computer Programming**

Cr. 2.

*Prereq: Com S 104*

8-week course in programming, including instruction in syntax and semantics, of the following current programming languages.

##### **COM S 105A: Short Course in Computer Programming: Perl**

(1-2) Cr. 2.

*Prereq: Com S 104*

8-week course in programming using Perl.

##### **COM S 105B: Short Course in Computer Programming: MATLAB**

(2-0) Cr. 2.

*Prereq: Com S 104*

8-week course in programming using MATLAB.

##### **COM S 106: Introduction to Web Programming**

(3-0) Cr. 3. F.S.

Introduction to web programming basics. Fundamentals of developing web pages using a comprehensive web development life cycle. Learn to code programs and earn in-depth experience with current web design techniques such as HTML5 and cascading style sheets. Programming with JavaScript, jQuery, PHP, SQL, and MySQL. Strategies for accessibility, usability and search engine optimization. No prior computer programming experience necessary.

##### **COM S 107: Windows Application Programming**

(3-0) Cr. 3. F.S.

Introduction to computer programming for non-majors using a language such as the Visual Basic language. Basics of good programming and algorithm development. Graphical user interfaces.

##### **COM S 108: Applied Computer Programming for Non-Majors**

(3-0) Cr. 3.

*Prereq: Com S 107 or equivalent*

Advanced programming applications in Visual Basic for non-majors. Emphasis on programming projects including sorting, file processing, database processing, web programming, and graphics and animation. Students will learn problem solving techniques and advanced programming skills to build real-world applications.

**COM S 113: Introduction to Spreadsheets and Databases**

(2-2) Cr. 3. F.S.SS.

Using Microsoft Excel spreadsheets and Microsoft Access databases to input, store, process, manipulate, query, and analyze data for business and industrial applications. Credit in Com S 113 may not be applied toward graduation in the COM S, S E, and CPR E majors.

**COM S 127: Introduction to Computer Programming**

(3-2) Cr. 4. F.S.

*Prereq: Credit or Enrollment in MATH 140 or higher*

Introduction to computer programming with an emphasis on problem solving. Topics include: program structures, expressions, variables, decision and logic, iteration, collections, input and output. Program construction and testing. Programming assignments including games and applications. No prior programming experience necessary. This course is intended for Computer Science majors.

**COM S 203: Careers in Computer Science**

Cr. R. F.S.

Computer science as a profession. Introduction to career fields open to computer science majors. Relationship of coursework to careers. Presentations by computer science professionals. Offered on a satisfactory-fail basis only.

**COM S 207: Fundamentals of Computer Programming**

(Cross-listed with MIS). (3-1) Cr. 3. F.S.SS.

*Prereq: MATH 150 or placement into MATH 140 or higher*

An introduction to computer programming using an object-oriented programming language. Emphasis on the basics of good programming techniques and style. Extensive practice in designing, implementing, and debugging small programs. Use of abstract data types. Interactive and file I/O. This course is not designed for computer science, software engineering, and computer engineering majors. Credit may not be applied toward graduation for both Com S 207/MIS 207 and Com S 227.

**COM S 208: Intermediate Computer Programming**

(3-1) Cr. 3.

*Prereq: MIS/COM S 207, credit or enrollment in MATH 151, MATH 160, or MATH 165*

Intermediate-level programming techniques. Emphasis on designing, writing, testing, debugging, and documenting medium-sized programs. Data structures and their uses. Dynamic memory usage. Inheritance and polymorphism. Algorithm design and efficiency: recursion, searching, and sorting. Event-driven and GUI programming. The software development process. This course is not designed for computer science, software engineering and computer engineering majors. Credit may not be applied toward the major in computer science, software engineering, or computer engineering.

**COM S 227: Object-oriented Programming**

(3-2) Cr. 4. F.S.SS.

*Prereq: Credit or Enrollment in MATH 143 or higher; recommended: a previous high school or college course in programming or equivalent experience.*

Computer programming using objects as the mechanism for modularity, abstraction, and code reuse. Instance variables, methods, and encapsulation. Review of control structures for conditionals and iteration. Developing algorithms on strings, arrays, and lists. Recursion, searching, and sorting. Text parsing and file I/O. Interfaces, inheritance, polymorphism, and abstract classes. Exception handling. Tools for unit testing and debugging. Emphasis on a disciplined approach to specification, code development, and testing. Course intended for Com S majors. Credit may not be applied toward graduation for both Com S 207 and 227.

**COM S 228: Introduction to Data Structures**

(3-1) Cr. 3. F.S.SS.

*Prereq: Minimum of C- in COM S 227, credit or enrollment in MATH 165*

An object-oriented approach to data structures and algorithms. Object-oriented analysis, design, and programming, with emphasis on data abstraction, inheritance and subtype polymorphism, and generics. Abstract data type specification and correctness. Collections including lists, stacks, queues, trees, heaps, maps, hash tables, and graphs. Big-O notation and algorithm analysis. Searching and sorting. Graph search and shortest path algorithms. Emphasis on object-oriented design, writing and documenting medium-sized programs. This course is designed for majors.

**COM S 230: Discrete Computational Structures**

(Cross-listed with MATH). (3-1) Cr. 3. F.S.SS.

*Prereq: Minimum of C- in COM S 227 and MATH 165; ENGL 150*

Concepts in discrete mathematics as applied to computer science. Logic, set theory, functions, relations, combinatorics, discrete probability, graph theory and number theory. Proof techniques, induction and recursion.

**COM S 252: Linux Operating System Essentials**

(3-0) Cr. 3. F.

*Prereq: CPR E 185 or S E 185 or COM S 127 or COM S 207 or COM S 227*

Introduction to installation, utilization, and administration of Linux systems. Topics include open-source software, package installation and management, shell programming and command-line utilities, process and service management, account management, network configuration, file sharing, interoperation with other computers and operating systems, automation, and system security.

**COM S 290: Independent Study**

Cr. arr. Repeatable, maximum of 6 credits. F.S.SS.

*Prereq: Permission of instructor*

No more than 6 credits of Com S 290 or Com S 290H may be counted toward graduation.

**COM S 290H: Independent Study: Honors**

Cr. arr. Repeatable, maximum of 6 credits. F.S.

*Prereq: Permission of instructor*

No more than 6 credits of Com S 290 or Com S 290H may be counted toward graduation.

**COM S 309: Software Development Practices**

(Cross-listed with S E). (3-1) Cr. 3. F.S.

*Prereq: Minimum of C- in COM S 228 and MATH 165*

A practical introduction to methods for managing software development. Process models, requirements analysis, structured and object-oriented design, coding, testing, maintenance, cost and schedule estimation, metrics. Programming projects.

**COM S 311: Introduction to the Design and Analysis of Algorithms**

(3-1) Cr. 3. F.S.SS.

*Prereq: Minimum of C- in COM S 228; MATH 166, ENGL 150, and COM S 230 or CPR E 310*

Basic techniques for design and analysis of algorithms. Sorting, searching, graph algorithms, string matching, and NP-completeness. Design techniques such as dynamic programming, divide and conquer, greedy method, and approximation. Asymptotic, worst-case, average-case and amortized analyses. Topics from advanced data structures such as balanced trees and hashing.

**COM S 319: Construction of User Interfaces**

(Cross-listed with S E). (3-0) Cr. 3. F.S.

*Prereq: COM S 228*

Overview of user interface design. Evaluation and testing of user interfaces. Review of principles of object orientation, object oriented design and analysis using UML in the context of user interface design. Design of windows, menus and commands. Developing Web and Windows-based user-interfaces. Event-driven programming. Introduction to Frameworks and APIs for the construction of user interfaces.

**COM S 321: Introduction to Computer Architecture and Machine-Level Programming**

(3-1) Cr. 3. F.S.

*Prereq: Minimum of C- in COM S 228 and MATH 165; COM S 230 or CPR E 281; ENGL 250*

Introduction to computer architecture and organization. Emphasis on evaluation of performance, instruction set architecture, datapath and control, memory-hierarchy design, and pipelining. Assembly language programming.

**COM S 326: C for Programmers**

Cr. 1. F.S.

*Prereq: Minimum of C- in COM S 228; COM S 230*

Half-semester course. Design and implementation of libraries and applications in C, for students with prior programming background. Emphasis on differences between C and other languages, including file I/O, string processing, memory management, and buffer overruns. Using build systems, debuggers, and other development tools. Programming projects.

**COM S 327: Advanced Programming Techniques**

(3-0) Cr. 3. F.S.

*Prereq: Minimum of C- in COM S 228 and MATH 165*

Object-oriented programming experience using a language suitable for exploring advanced topics in programming. Topics include memory management, parameter passing, inheritance, compiling, debugging, and maintaining programs. Significant programming projects.

**COM S 331: Theory of Computing**

(Cross-listed with LING). (3-1) Cr. 3. F.S.

*Prereq: Minimum of C- in COM S 228, MATH 166, and in COM S 230 or CPR E 310; ENGL 250*

Models of computation: finite state automata, pushdown automata and Turing machines. Study of grammars and their relation to automata. Limits of digital computation, unsolvability and Church-Turing thesis. Relations between classes of languages.

**COM S 336: Introduction to Computer Graphics**

(3-0) Cr. 3. F.

*Prereq: COM S 327, CoReq MATH 207 or MATH 317*

Programming interactive computer graphics systems using standard low-level libraries (such as OpenGL or DirectX) with an emphasis on 3D rendering. The graphics pipeline and programmable shaders. Coordinate systems and transformations in two and three dimensions. Homogeneous coordinates, viewing transformations and perspective. Euler angles and quaternions. Visible surface algorithms. Lighting models and shading. Texture mapping, bump mapping, reflection, elementary ray tracing. Offscreen buffers, render-to-texture and related techniques.

**COM S 342: Principles of Programming Languages**

(Cross-listed with S E). (3-1) Cr. 3. F.S.

*Prereq: Minimum of C- in COM S 228 and MATH 165; COM S 230 or CPR E 310*

Study of concepts in programming languages, especially functional programming concepts. Overview of major programming paradigms, their relationship, and tradeoffs among paradigms enabling sound choices of programming language for application-specific development. Programming projects.

**COM S 350: Number Theory**

(Cross-listed with MATH). (3-0) Cr. 3. S.

*Prereq: MATH 201 or COM S 230*

Divisibility, integer representations, primes and divisors, linear diophantine equations, congruences, and multiplicative functions.

Applications to cryptography. Additional topics, chosen at the discretion of the instructor.

**COM S 352: Introduction to Operating Systems**

(3-1) Cr. 3. F.S.

*Prereq: COM S 321 or CPR E 381 and COM S 327 or CPR E 288; ENGL 250*

Survey of operating system, networking and parallel programming issues.

Introduction of processes, threads, process synchronization, deadlocks, memory, file systems, networking, security threats and encryption.

Programming projects.

**COM S 362: Object-Oriented Analysis and Design**

(Cross-listed with S E). (3-0) Cr. 3. F.S.

*Prereq: Minimum of C- in COM S 228 and MATH 165; ENGL 250*

Object-oriented requirements analysis and systems design. Design notations such as the Unified Modeling Language. Design Patterns.

Group design and programming with large programming projects.

**COM S 363: Introduction to Database Management Systems**

(3-0) Cr. 3. F.S.

*Prereq: Minimum of C- in COM S 228 and MATH 165; ENGL 250*

Relational, object-oriented, semistructured and query languages. SQL, XML, and NO-SQL. Database design using entity-relationship model, data dependencies, and relational database design. Application development

in SQL-like languages and general purpose host languages with application program interfaces and a commonly used Object Relational Mapping framework. Web application development. Programming Projects.

**COM S 398: Cooperative Education**

Cr. R. Repeatable. F.S.SS.

*Prereq: Permission of department chair*

Required of all cooperative education students. Students must register for this course prior to commencing each work period.

**COM S 402: Computer Science Senior Project**

Cr. 2-3. Repeatable, maximum of 6 credits. F.S.

*Prereq: COM S 309, COM S 311, COM S 321, and COM S 331, Senior Classification*

Students work as individuals and teams to complete the planning, design, and implementation of a significant project in the topic area. Oral and written reports. No more than 6 credits of 402A, 402B, and 402C may be used toward graduation.

**COM S 402A: Computer Science Senior Project: Multimedia and Computer Gaming I**

Cr. 2-3. Repeatable, maximum of 6 credits. F.

*Prereq: COM S 309, COM S 311, COM S 321, COM S 331, and COM S 437, Senior Classification*

Students conceive, plan, architect and design a computer game. Student registered in this course will work with students in ARTIS 409. Oral and written reports. No more than 6 credits of 402A, 402B, and 402C may be used toward graduation.

**COM S 402B: Computer Science Senior Project: Multimedia and Computer Gaming II**

Cr. 2-3. Repeatable, maximum of 6 credits. S.

*Prereq: COM S 402A, Senior Classification*

Students implement, test, and present a completed production computer game. Students in this class will work with students in ARTIS 409. Oral and written reports. No more than 6 credits of 402A, 402B, and 402C may be used toward graduation.

**COM S 402C: Computer Science Senior Project: Project in Computer Science**

(0-6) Cr. 2-3. Repeatable, maximum of 6 credits. F.S.

*Prereq: COM S 309, COM S 311, COM S 321, and COM S 331, Senior Classification*

Students work as individuals and teams to complete the planning, design, and implementation of a significant project in the topic area. Oral and written reports. No more than 6 credits of 402A, 402B, and 402C may be used toward graduation.

**COM S 409: Software Requirements Engineering**

(Dual-listed with COM S 509). (3-0) Cr. 3.

*Prereq: COM S 309; for graduate credit: graduate standing or permission of instructor*

The requirements engineering process including elicitation, requirements analysis fundamentals, requirements specification and communication, and requirements evaluation. Modeling of functional and nonfunctional requirements, traceability, and requirements change management. Case studies and software projects.

**COM S 410: Distributed Development of Software**

(Dual-listed with COM S 510). (3-0) Cr. 3.

*Prereq: COMS 228, COMS 309, COMS 327; for graduate credit: graduate standing or permission of instructor*

Teams of students develop software applications in a modern software engineering environment. Importance, effective processes pertaining to team organization, management and communication, and cultural issues of distributed development. Graduate credit requires in-depth study of concepts and oral presentations.

**COM S 412: Formal Methods in Software Engineering**

(Dual-listed with COM S 512). (Cross-listed with CPR E, S E). (3-0) Cr. 3.

*Prereq: COM S 311, STAT 330; for graduate credit: graduate standing or permission of instructor*

A study of formal techniques for model-based specification and verification of software systems. Topics include logics, formalisms, graph theory, numerical computations, algorithms and tools for automatic analysis of systems. Graduate credit requires in-depth study of concepts.

**COM S 413: Foundations and Applications of Program Analysis**

(Dual-listed with COM S 513). Cr. 3.

*Prereq: COM S 331, COM S 342*

Algorithms and tools for automatically reasoning about code and program executions to predict software behavior. Theory and foundations related to control flow analysis, dataflow analysis, abstract interpretation and symbolic execution. Applications of program analysis to improve software security, performance and testing. Concepts, algorithms, tools, benchmarks, methodologies for solving problems using program analysis and for preparing research in program analysis.

**COM S 414: Gerontechnology in Smart Home Environments**

(Dual-listed with COM S 514). (3-0) Cr. 3.

*Prereq: COM S 227 or COM S 207 or GERON 377 or ARTGR 271 or equivalent; for graduate credit: graduate standing or permission of instructor*

Interdisciplinary course designed for students interested in assistive technology, pervasive computing, mobile computing and principles of universal and inclusive design for end users, in particular, the elderly population. Students work in semester-long projects as interdisciplinary teams to apply knowledge obtained from lectures and mutual presentations. Research report and oral presentation required for graduate credit.

**COM S 415: Software System Safety**

(Dual-listed with COM S 515). (3-0) Cr. 3.

*Prereq: COM S 309 or COM S 311; for graduate credit: graduate standing or permission of instructor*

An introduction to the hazard analysis, safety requirements, design, and testing of software for safety-critical and high-dependability systems. Safety analysis techniques, fault identification and recovery, and certification issues. Emphasizes a case-based and systematic approach to software's role in safe systems.

**COM S 417: Software Testing**

(Cross-listed with S E). (3-0) Cr. 3.

*Prereq: COM S 309; COM S 230 or CPR E 310; ENGL 250, SP CM 212*

An introduction to software testing principles and techniques. Test models, test design, test adequacy criteria; regression, integration, and system testing; and software testing tools.

**COM S 418: Introduction to Computational Geometry**

(Dual-listed with COM S 518). (3-0) Cr. 3.

*Prereq: COM S 311 or permission of instructor; for graduate credit: graduate standing or permission of instructor*

Introduction to data structures, algorithms, and analysis techniques for computational problems that involve geometry. Convex hulls, line segment intersection, polygon triangulation, 2D linear programming, range queries, point location, arrangements and duality, Voronoi diagrams, Delaunay triangulations, geometric data structures, robot motion planning, visibility graphs. Other selected topics. Programming assignments. Scholarly report required for graduate credit.

**COM S 421: Logic for Mathematics and Computer Science**

(Cross-listed with MATH). (3-0) Cr. 3.

*Prereq: MATH 301 or MATH 207 or MATH 317 or COM S 230*

Propositional and predicate logic. Topics selected from Horn logic, equational logic, resolution and unification, foundations of logic programming, reasoning about programs, program specification and verification, model checking and binary decision diagrams, temporal logic and modal logic.

**COM S 424: Introduction to High Performance Computing**

(Cross-listed with CPR E, MATH). (2-2) Cr. 3. F.

*Prereq: MATH 265; MATH 207 or MATH 317; or permission of instructor.*

Unix, serial programming of scientific applications, OpenMP for shared-memory parallelization. No Unix, Fortran or C experience required.

**COM S 425: High Performance Computing for Scientific and Engineering Applications**

(Cross-listed with CPR E). (2-2) Cr. 3.

*Prereq: COM S 311, ENGL 250, SP CM 212*

Introduction to high performance computing platforms including parallel computers and workstation clusters. Discussion of parallel architectures, performance, programming models, and software development issues. Sample applications from science and engineering. Practical issues in high performance computing will be emphasized via a number of programming projects using a variety of programming models and case studies. Oral and written reports.

**COM S 426: Introduction to Parallel Algorithms and Programming**

(Dual-listed with COM S 526). (Cross-listed with CPR E). (3-2) Cr. 4. F.

*Prereq: CPR E 308 or COM S 321, CPR E 315 or COM S 311*

Models of parallel computation, performance measures, basic parallel constructs and communication primitives, parallel programming using MPI, parallel algorithms for selected problems including sorting, matrix, tree and graph problems, fast Fourier transforms.

**COM S 430: Concurrent Programming in Practice**

(3-1) Cr. 3.

*Prereq: COM S 311, COM S 362 or COM S 363, ENGL 250, SP CM 212*

A practical course in concepts, techniques, languages, and frameworks for concurrent and asynchronous systems. Concurrency fundamentals: threads, synchronization locks, waiting and notification, memory visibility. Immutability and thread confinement. Concurrent data structures and utilities, thread pools. Asynchronous programming with callbacks, futures, and message passing. Issues of aliasing, ownership and borrowing. Transactional memory, immutable and versioned data structures. Alternatives to threads and locks: event-driven systems, the actor model, CSP, coroutines. Students will investigate several non-mainstream languages supporting different concurrency models. Oral and written reports.

**COM S 433: Molecular Programming of Nanoscale Devices and Processes**

(Dual-listed with COM S 533). (3-0) Cr. 3.

*Prereq: Minimum of C- in COM S 331 or permission of instructor; for graduate credit: graduate standing or permission of instructor*

Programming, modeling, and analysis of natural and engineered systems at the nanoscale. Topics include chemical reaction networks, strand displacement systems, models of self-assembly, biomolecular origami, and molecular robotics. Emphasis on mathematical methods of describing, simulating, programming, and assessing the computational power of such systems. Graduate credit requires a written or oral report on current research.

**COM S 435: Algorithms for Large Data Sets: Theory and Practice**

(Dual-listed with COM S 535). (3-0) Cr. 3.

*Prereq: COM S 311 or equivalent; for graduate credit: graduate standing or permission of instructor*

Algorithmic challenges involved in solving computational problems on massive data sets. Probabilistic data structures, Curse of Dimensionality and dimensionality reduction, locality sensitive hashing, similarity measures, matrix decompositions. Optimization problems in massive data analysis. Computational problems that arise in the context of web search, social network analysis, online advertising etc. Practical aspects include implementation and performance evaluation of the algorithms on real world data sets. Graduate credit requires a written report on current research.

**COM S 437: Computer Game and Media Programming**

(3-0) Cr. 3.

*Prereq: COM S 336 or permission of instructor*

Students will learn video game programming using current game engine interfaces with real hardware. Particular attention is paid to the development environment, tool chains, 2D graphics, 3D graphics, controllers, memory management, and audio systems.

**COM S 440: Principles and Practice of Compiling**

(Dual-listed with COM S 540). (3-1) Cr. 3.

*Prereq: COM S 331, COM S 342, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Theory of compiling and implementation issues of programming languages. Programming projects leading to the construction of a compiler. Projects with different difficulty levels will be given for 440 and 540. Topics include: lexical, syntactic and semantic analyses, syntax-directed translation, code generation, runtime environment and library support.

**COM S 441: Programming Languages**

(Dual-listed with COM S 541). (3-1) Cr. 3.

*Prereq: COM S 342 or COM S 440; for graduate credit: graduate standing or permission of instructor*

Survey of the goals and problems of language design. Formal and informal studies of a wide variety of programming language features including type systems. Creative use of functional and declarative programming paradigms.

**COM S 444: Bioinformatic Analysis**

(Cross-listed with BCB, BCBO, BIOL, CPR E, GEN). (4-0) Cr. 4. F.

*Prereq: MATH 165 and Introductory Statistics (STAT 101, STAT 104, STAT 105, STAT 201, or STAT 330).*

Broad overview of bioinformatics with a significant problem-solving component, including hands-on practice using computational tools to solve a variety of biological problems. Topics include: bioinformatic data processing, Python programming, genome assembly, database search, sequence alignment, gene prediction, next-generation sequencing, comparative and functional genomics, and systems biology.

**COM S 453: Privacy Preserving Algorithms and Data Security**

Cr. 3.

*Prereq: COM S 311*

Fundamentals of privacy preserving algorithms, data security, anonymization, and techniques and mechanisms to minimize disclosure of sensitive information while maintaining availability. Theory and fundamentals underpinning measures to evaluate the privacy and availability of data; implementation and deployment of privacy-preserving data operations including pre- and post-randomization techniques, homomorphisms, and secure function evaluation protocols. Theory and practice of the algorithmic limits on data privacy, including the cost in terms of time and space complexity.

**COM S 454: Distributed Systems**

(Dual-listed with COM S 554). (Cross-listed with CPR E). (3-1) Cr. 3.

*Prereq: COM S 311, COM S 352; for graduate credit: graduate standing or permission of instructor*

Theoretical and practical issues of design and implementation of distributed systems. The client server paradigm, inter-process communications, synchronization and concurrency control, naming, consistency and replication, fault tolerance, and distributed file systems. Graduate credit requires additional in-depth study of concepts. Programming projects and written reports.

**COM S 455: Simulation: Algorithms and Implementation**

(Dual-listed with COM S 555). (3-0) Cr. 3.

*Prereq: COM S 311 and COM S 230, STAT 330, ENGL 150, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Introduction to discrete-event simulation with a focus on computer science applications, including performance evaluation of networks and distributed systems. Overview of algorithms and data structures necessary to implement simulation software. Discrete and continuous stochastic models, random number generation, elementary statistics, simulation of queuing and inventory systems, Monte Carlo simulation, point and interval parameter estimation. Graduate credit requires additional in-depth study of concepts.

**COM S 461: Principles and Internals of Database Systems**

(Dual-listed with COM S 561). (3-1) Cr. 3.

*Prereq: COM S 311, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Database design including entity-relationship model, relational data model, and non-relational data models, data dependency, and normalization. Database management including physical storage, access methods, query processing, and transaction management. Database systems of special purposes such as spatial databases, mobile object databases, and multimedia databases. Introduction to current database research such as cloud data management and Internet information retrieval.

**COM S 472: Principles of Artificial Intelligence**

(Dual-listed with COM S 572). (3-1) Cr. 3.

*Prereq: COM S 311, STAT 330 or STAT 305, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Specification, design, implementation, and selected applications of intelligent software agents and multi-agent systems. Computational models of intelligent behavior, including problem solving, knowledge representation, reasoning, planning, decision making, learning, perception, action, communication and interaction. Reactive, deliberative, rational, adaptive, learning and communicative agents and multiagent systems. Artificial intelligence programming. Research project and written report required for graduate credit.

**COM S 474: Introduction to Machine Learning**

(Dual-listed with COM S 574). (3-1) Cr. 3.

*Prereq: COM S 311, STAT 330 or STAT 305, MATH 165, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Introduction to tools and techniques of machine learning for applications. Selected machine learning techniques in practical data mining for classification, regression, and clustering, e.g., association rules, decision trees, linear models, Bayesian learning, support vector machines, artificial neural networks, instance-based learning, probabilistic graphical models, ensemble learning, and clustering algorithms. Selected applications in data mining and pattern recognition.

**COM S 477: Problem Solving Techniques for Applied Computer Science**

(Dual-listed with COM S 577). (3-0) Cr. 3.

*Prereq: COM S 228; COM S 230 or CPR E 310, MATH 166, MATH 207 or MATH 317, or consent of the instructor; for graduate credit: graduate standing or permission of instructor*

Selected topics in applied mathematics, algorithms, and geometry that have found applications in areas such as geometric modeling, graphics, robotics, vision, human machine interface, speech recognition, computer animation, etc. Homogeneous coordinates and transformations, perspective projection, rotations in space, quaternions, polynomial interpolation, roots of polynomials and polynomial systems, solution of linear and nonlinear equations, parametric and algebraic curves, curvature, torsion, Frenet formulas, surfaces, principal curvatures, Gaussian and mean curvatures, geodesics, approximation, Fourier series and fast Fourier transform, linear programming, data fitting, least squares, simplex method, nonlinear optimization, Lagrange multipliers, calculus of variations. Programming components. Scholarly report required for graduate credit.

**COM S 481: Numerical Methods for Differential Equations**

(Cross-listed with MATH). (3-0) Cr. 3. S.

*Prereq: MATH 265 and either MATH 266 or MATH 267*

First order Euler method, high order Runge-Kutta methods, and multistep methods for solving ordinary differential equations. Finite difference and finite element methods for solving partial differential equations. Local truncation error, stability, and convergence for finite difference method. Numerical solution space, polynomial approximation, and error estimate for finite element method. Computer programming required.

**COM S 486: Fundamental Concepts in Computer Networking**

(3-0) Cr. 3.

*Prereq: COM S 352*

An introduction to fundamental concepts in the design and implementation of computer communication in both wired and wireless networks, their protocols, and applications. Layered network architecture in the Internet, applications, transport, network, and data link layers and their protocols, Socket API, software-defined networking, and network security.

**COM S 487: Network Programming, Applications, and Research Issues**

(Dual-listed with COM S 587). (3-0) Cr. 3.

*Prereq: Com S 352 or CPR E 489 or equivalent; for graduate credit: graduate standing or permission of instructor*

Programming paradigms for building distributed and networking applications, including multithreaded client-server programming, socket programming, distributed object frameworks and programming suites, and web computing and security. Introduction to some on-going research issues in distributed and networking applications, including peer-to-peer computing, multimedia communications, and mobile computing and networking. Written report and oral presentation required for graduate credit.

**COM S 490: Independent Study**

Cr. arr. Repeatable, maximum of 9 credits. F.S.SS.

*Prereq: 6 credits in computer science, permission of instructor*

No more than 9 credits of Com S 490 or Com S 490H may be counted toward graduation.

**COM S 490H: Independent Study: Honors**

Cr. arr. Repeatable, maximum of 9 credits. F.S.

*Prereq: 6 credits in computer science, permission of instructor*

No more than 9 credits of Com S 490 or Com S 490H may be counted toward graduation.

**Courses primarily for graduate students, open to qualified undergraduates:****COM S 509: Software Requirements Engineering**

(Dual-listed with COM S 409). (3-0) Cr. 3.

*Prereq: COM S 309; for graduate credit: graduate standing or permission of instructor*

The requirements engineering process including elicitation, requirements analysis fundamentals, requirements specification and communication, and requirements evaluation. Modeling of functional and nonfunctional requirements, traceability, and requirements change management. Case studies and software projects.

**COM S 510: Distributed Development of Software**

(Dual-listed with COM S 410). (3-0) Cr. 3.

*Prereq: COMS 228, COMS 309, COMS 327; for graduate credit: graduate standing or permission of instructor*

Teams of students develop software applications in a modern software engineering environment. Importance, effective processes pertaining to team organization, management and communication, and cultural issues of distributed development. Graduate credit requires in-depth study of concepts and oral presentations.

**COM S 511: Design and Analysis of Algorithms**

(Cross-listed with CPR E). (3-0) Cr. 3.

*Prereq: COM S 311*

A study of algorithm design and analysis techniques. Network flows and linear programming. Randomized algorithms. NP-completeness. Approximation algorithms. Fixed-parameter algorithms.

**COM S 512: Formal Methods in Software Engineering**

(Dual-listed with COM S 412). (3-0) Cr. 3.

*Prereq: COM S 311, STAT 330; for graduate credit: graduate standing or permission of instructor*

A study of formal techniques for model-based specification and verification of software systems. Topics include logics, formalisms, graph theory, numerical computations, algorithms and tools for automatic analysis of systems. Graduate credit requires in-depth study of concepts.

**COM S 513: Foundations and Applications of Program Analysis**

(Dual-listed with COM S 413). (Cross-listed with CPR E). Cr. 3.

*Prereq: COM S 331, COM S 342*

Algorithms and tools for automatically reasoning about code and program executions to predict software behavior. Theory and foundations related to control flow analysis, dataflow analysis, abstract interpretation and symbolic execution. Applications of program analysis to improve software security, performance and testing. Concepts, algorithms, tools, benchmarks, methodologies for solving problems using program analysis and for preparing research in program analysis.

**COM S 514: Gerontechnology in Smart Home Environments**

(Dual-listed with COM S 414). (3-0) Cr. 3.

*Prereq: COM S 227 or COM S 207 or GERON 377 or ARTGR 271 or equivalent; for graduate credit: graduate standing or permission of instructor*

Interdisciplinary course designed for students interested in assistive technology, pervasive computing, mobile computing and principles of universal and inclusive design for end users, in particular, the elderly population. Students work in semester-long projects as interdisciplinary teams to apply knowledge obtained from lectures and mutual presentations. Research report and oral presentation required for graduate credit.

**COM S 515: Software System Safety**

(Dual-listed with COM S 415). (3-0) Cr. 3.

*Prereq: COM S 309 or COM S 311; for graduate credit: graduate standing or permission of instructor*

An introduction to the hazard analysis, safety requirements, design, and testing of software for safety-critical and high-dependability systems. Safety analysis techniques, fault identification and recovery, and certification issues. Emphasizes a case-based and systematic approach to software's role in safe systems.

**COM S 518: Introduction to Computational Geometry**

(Dual-listed with COM S 418). (3-0) Cr. 3.

*Prereq: COM S 311 or permission of instructor; for graduate credit: graduate standing or permission of instructor*

Introduction to data structures, algorithms, and analysis techniques for computational problems that involve geometry. Convex hulls, line segment intersection, polygon triangulation, 2D linear programming, range queries, point location, arrangements and duality, Voronoi diagrams, Delaunay triangulations, geometric data structures, robot motion planning, visibility graphs. Other selected topics. Programming assignments. Scholarly report required for graduate credit.

**COM S 525: Numerical Analysis of High Performance Computing**

(Cross-listed with CPR E, MATH). (3-0) Cr. 3. S.

*Prereq: CPR E 308 or MATH 481; experience in scientific programming; knowledge of FORTRAN or C*

Introduction to parallelization techniques and numerical methods for distributed memory high performance computers. A semester project in an area related to each student's research interests is required.

**COM S 526: Introduction to Parallel Algorithms and Programming**

(Dual-listed with COM S 426). (Cross-listed with CPR E). (3-2) Cr. 4. F.

*Prereq: CPR E 308 or COM S 321, CPR E 315 or COM S 311*

Models of parallel computation, performance measures, basic parallel constructs and communication primitives, parallel programming using MPI, parallel algorithms for selected problems including sorting, matrix, tree and graph problems, fast Fourier transforms.

**COM S 531: Theory of Computation**

(3-0) Cr. 3.

*Prereq: COM S 331*

A systematic study of the fundamental models and analytical methods of theoretical computer science. Computability, the Church-Turing thesis, decidable and undecidable problems. Computational resources such as time, space, and nonuniformity. Complexity classes, computational intractability and completeness. Selected topics from randomness, algorithmic information theory, and logic.

**COM S 533: Molecular Programming of Nanoscale Devices and Processes**

(Dual-listed with COM S 433). (3-0) Cr. 3.

*Prereq: Minimum of C- in COM S 331 or permission of instructor; for graduate credit: graduate standing or permission of instructor*

Programming, modeling, and analysis of natural and engineered systems at the nanoscale. Topics include chemical reaction networks, strand displacement systems, models of self-assembly, biomolecular origami, and molecular robotics. Emphasis on mathematical methods of describing, simulating, programming, and assessing the computational power of such systems. Graduate credit requires a written or oral report on current research.

**COM S 535: Algorithms for Large Data Sets: Theory and Practice**

(Dual-listed with COM S 435). (3-0) Cr. 3.

*Prereq: COM S 311 or equivalent; for graduate credit: graduate standing or permission of instructor*

Algorithmic challenges involved in solving computational problems on massive data sets. Probabilistic data structures, Curse of Dimensionality and dimensionality reduction, locality sensitive hashing, similarity measures, matrix decompositions. Optimization problems in massive data analysis. Computational problems that arise in the context of web search, social network analysis, online advertising etc. Practical aspects include implementation and performance evaluation of the algorithms on real world data sets. Graduate credit requires a written report on current research.

**COM S 540: Principles and Practice of Compiling**

(Dual-listed with COM S 440). (3-1) Cr. 3.

*Prereq: COM S 331, COM S 342, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Theory of compiling and implementation issues of programming languages. Programming projects leading to the construction of a compiler. Projects with different difficulty levels will be given for 440 and 540. Topics include: lexical, syntactic and semantic analyses, syntax-directed translation, code generation, runtime environment and library support.

**COM S 541: Programming Languages**

(Dual-listed with COM S 441). (3-1) Cr. 3.

*Prereq: COM S 342 or COM S 440; for graduate credit: graduate standing or permission of instructor*

Survey of the goals and problems of language design. Formal and informal studies of a wide variety of programming language features including type systems. Creative use of functional and declarative programming paradigms.

**COM S 544: Fundamentals of Bioinformatics**

(Cross-listed with BCB, CPR E, GDCB). (4-0) Cr. 4. F.

*Prereq: MATH 165 or STAT 401 or equivalent*

A practical, hands-on overview of how to apply bioinformatics to biological research. Recommended for biologists desiring to gain computational molecular biology skills. Topics include: sequence analysis, genomics, proteomics, phylogenetic analyses, ontology enrichment, systems biology, data visualization and emergent technologies.

**COM S 549: Advanced Algorithms in Computational Biology**

(Cross-listed with CPR E). (3-0) Cr. 3.

*Prereq: COM S 311 and either COM S 228 or COM S 208*

Design and analysis of algorithms for applications in computational biology, pairwise and multiple sequence alignments, approximation algorithms, string algorithms including in-depth coverage of suffix trees, semi-numerical string algorithms, algorithms for selected problems in fragment assembly, phylogenetic trees and protein folding. No background in biology is assumed. Also useful as an advanced algorithms course in string processing.

**COM S 551: Computational Techniques for Genome Assembly and Analysis**

(3-0) Cr. 3.

*Prereq: COM S 311 and some knowledge of programming*

Introduction to a big data research area in bioinformatics. Focus on applying computational techniques to huge genomic sequence data. These techniques include finding optimal sequence alignments, generating genome assemblies, finding genes in genomic sequences, mapping short sequences onto a genome assembly, finding single-nucleotide and structural variations, building phylogenetic trees from genome sequences, and performing genome-wide association studies.

**COM S 552: Principles of Operating Systems**

(3-0) Cr. 3.

*Prereq: For graduate credit: graduate standing or permission of instructor*

A comparative study of high-level language facilities for process synchronization and communication. Analysis of deadlock, concurrency control and recovery. Protection issues including capability-based systems, access and flow control, encryption, and authentication. Additional topics chosen from distributed operating systems, soft real-time operating systems, and advanced security issues. Programming and research projects.

**COM S 554: Distributed Systems**

(Dual-listed with COM S 454). (Cross-listed with CPR E). (3-1) Cr. 3.

*Prereq: COM S 311, COM S 352; for graduate credit: graduate standing or permission of instructor*

Theoretical and practical issues of design and implementation of distributed systems. The client server paradigm, inter-process communications, synchronization and concurrency control, naming, consistency and replication, fault tolerance, and distributed file systems. Graduate credit requires additional in-depth study of concepts. Programming projects and written reports.

**COM S 555: Simulation: Algorithms and Implementation**

(Dual-listed with COM S 455). (3-0) Cr. 3.

*Prereq: COM S 311 and COM S 230, STAT 330, ENGL 150, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Introduction to discrete-event simulation with a focus on computer science applications, including performance evaluation of networks and distributed systems. Overview of algorithms and data structures necessary to implement simulation software. Discrete and continuous stochastic models, random number generation, elementary statistics, simulation of queuing and inventory systems, Monte Carlo simulation, point and interval parameter estimation. Graduate credit requires additional in-depth study of concepts.

**COM S 556: Analysis Algorithms for Stochastic Models**

(3-0) Cr. 3.

*Prereq: Graduate standing or permission of instructor*

Introduction to the use of stochastic models to study complex systems, including network communication and distributed systems. Data structures and algorithms for analyzing discrete-state models expressed in high-level formalisms. State space and reachability graph construction, model checking, Markov chain construction and numerical solution, computation of performance measures, product-form models, approximations, and advanced techniques.

**COM S 557: Computer Graphics and Geometric Modeling**

(Cross-listed with CPR E, M E). (3-0) Cr. 3. F.

*Prereq: M E 421, programming experience in C*

Fundamentals of computer graphics technology. Data structures. Parametric curve and surface modeling. Solid model representations. Applications in engineering design, analysis, and manufacturing.

**COM S 558: Introduction to the 3D Visualization of Scientific Data**

(Cross-listed with GEOL, HCI). (2-2) Cr. 3. Alt. F., offered even-numbered years.

*Prereq:* Graduate-student standing in the mathematical or natural sciences or engineering; basic programming knowledge

Introduction to visualizing scientific information with 3D computer graphics and their foundation in human perception. Overview of different visualization techniques and examples of 3D visualization projects from different disciplines (natural sciences, medicine, and engineering). Class project in interactive 3D visualization using the ParaView, Mayavi, TVTK, VTK or a similar system.

**COM S 559: Security and Privacy in Cloud Computing**

(Cross-listed with CPR E). Cr. 3.

*Prereq:* COM S 352 or CPR E 308, and COM S 486 or CPR E 489 or CPR E 530

Introduction to cloud computing concepts and systems. Security and privacy threats in cloud computing. Practical techniques for cloud computing security. Theoretical and practical solutions for secure outsourcing of data and computation. Oral presentations and research projects.

**COM S 560: Data-Driven Security and Privacy**

(Cross-listed with CPR E, INFAS). Cr. 3. Alt. S., offered irregularly.

*Prereq:* CPR E 531; COM S 474 or COM S 573

Examination of applications of machine learning and big data techniques to various security and privacy problems, as well as secure and privacy-preserving machine learning algorithms.

**COM S 561: Principles and Internals of Database Systems**

(Dual-listed with COM S 461). (3-1) Cr. 3.

*Prereq:* COM S 311, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor

Database design including entity-relationship model, relational data model, and non-relational data models, data dependency, and normalization. Database management including physical storage, access methods, query processing, and transaction management. Database systems of special purposes such as spatial databases, mobile object databases, and multimedia databases. Introduction to current database research such as cloud data management and Internet information retrieval.

**COM S 567: Bioinformatics I (Bioinformatics Algorithms)**

(Cross-listed with BCB, CPR E). (3-0) Cr. 3.

*Prereq:* COM S 228; COM S 330; credit or enrollment in BIOL 315, STAT 430

Biology as an information science. A review of the algorithmic principles that are driving the advances in bioinformatics and computational biology.

**COM S 568: Bioinformatics II (Statistical Bioinformatics)**

(Cross-listed with BCB, GDCEB, STAT). (3-0) Cr. 3. S.

*Prereq:* BCB 567 or (BIOL 315 and STAT 430), credit or enrollment in GEN 409

Statistical models for sequence data, including applications in genome annotation, motif discovery, variant discovery, molecular phylogeny, gene expression analysis, and metagenomics. Statistical topics include model building, inference, hypothesis testing, and simple experimental design, including for big data/complex models.

**COM S 569: Bioinformatics III (Structural Bioinformatics)**

(Cross-listed with BBMB, BCB, CPR E, GDCEB). (3-0) Cr. 3. F.

*Prereq:* BCB 567, BBMB 316, GEN 409, STAT 430

Molecular structures including genes and gene products: protein, DNA and RNA structure. Structure determination methods, structural refinement, structure representation, comparison of structures, visualization, and modeling. Molecular and cellular structure from imaging. Analysis and prediction of protein secondary, tertiary, and higher order structure, disorder, protein-protein and protein-nucleic acid interactions, protein localization and function, bridging between molecular and cellular structures. Molecular evolution.

**COM S 570: Bioinformatics IV (Systems Biology)**

(Cross-listed with BCB, CPR E, GDCEB, STAT). (3-0) Cr. 3. S.

*Prereq:* BCB 567 or COM S 311, COM S 228, GEN 409, STAT 430

Algorithmic and statistical approaches in computational functional genomics and systems biology. Analysis of high throughput biological data obtained using system-wide measurements. Topological analysis, module discovery, and comparative analysis of gene and protein networks. Modeling, analysis, and inference of transcriptional regulatory networks, protein-protein interaction networks, and metabolic networks. Dynamic systems and whole-cell models. Ontology-driven, network based, and probabilistic approaches to information integration.

**COM S 572: Principles of Artificial Intelligence**

(Dual-listed with COM S 472). (3-1) Cr. 3.

*Prereq:* COM S 311, STAT 330 or STAT 305, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor

Specification, design, implementation, and selected applications of intelligent software agents and multi-agent systems. Computational models of intelligent behavior, including problem solving, knowledge representation, reasoning, planning, decision making, learning, perception, action, communication and interaction. Reactive, deliberative, rational, adaptive, learning and communicative agents and multiagent systems. Artificial intelligence programming. Research project and written report required for graduate credit.

**COM S 573: Machine Learning**

(3-1) Cr. 3.

*Prereq: Graduate standing or permission of instructor*

Basic principles, techniques, and applications of machine learning. Design, analysis, implementation, and applications of learning algorithms. Selected machine learning techniques in supervised learning, unsupervised learning, and reinforcement learning, including Bayesian decision theory, computational learning theory, decision trees, linear models, support vector machines, artificial neural networks, instance-based learning, probabilistic graphical models, ensemble learning, clustering algorithms, dimensionality reduction and feature selection. Selected applications in data mining and pattern recognition.

**COM S 574: Introduction to Machine Learning**

(Dual-listed with COM S 474). (3-1) Cr. 3.

*Prereq: COM S 311, STAT 330 or STAT 305, MATH 165, ENGL 250, SP CM 212; for graduate credit: graduate standing or permission of instructor*

Introduction to tools and techniques of machine learning for applications. Selected machine learning techniques in practical data mining for classification, regression, and clustering, e.g., association rules, decision trees, linear models, Bayesian learning, support vector machines, artificial neural networks, instance-based learning, probabilistic graphical models, ensemble learning, and clustering algorithms. Selected applications in data mining and pattern recognition.

**COM S 575: Computational Perception**

(Cross-listed with CPR E, HCI). (3-0) Cr. 3. S.

*Prereq: Graduate standing or permission of instructor*

Statistical and algorithmic methods for sensing, recognizing, and interpreting the activities of people by a computer. Focuses on machine perception techniques that facilitate and augment human-computer interaction. Introduce computational perception on both theoretical and practical levels. Participation in small groups to design, implement, and evaluate a prototype of a human-computer interaction system that uses one or more of the techniques covered in the lectures.

**COM S 577: Problem Solving Techniques for Applied Computer Science**

(Dual-listed with COM S 477). (3-0) Cr. 3.

*Prereq: COM S 228; COM S 230 or CPR E 310, MATH 166, MATH 207 or MATH 317, or consent of the instructor; for graduate credit: graduate standing or permission of instructor*

Selected topics in applied mathematics, algorithms, and geometry that have found applications in areas such as geometric modeling, graphics, robotics, vision, human machine interface, speech recognition, computer animation, etc. Homogeneous coordinates and transformations, perspective projection, rotations in space, quaternions, polynomial interpolation, roots of polynomials and polynomial systems, solution of linear and nonlinear equations, parametric and algebraic curves, curvature, torsion, Frenet formulas, surfaces, principal curvatures, Gaussian and mean curvatures, geodesics, approximation, Fourier series and fast Fourier transform, linear programming, data fitting, least squares, simplex method, nonlinear optimization, Lagrange multipliers, calculus of variations. Programming components. Scholarly report required for graduate credit.

**COM S 581: Computer Systems Architecture**

(Cross-listed with CPR E). (3-0) Cr. 3. F.

*Prereq: CPR E 381*

Quantitative principles of computer architecture design, instruction set design, processor architecture: pipelining and superscalar design, instruction level parallelism, memory organization: cache and virtual memory systems, multiprocessor architecture, cache coherency, interconnection networks and message routing, I/O devices and peripherals.

**COM S 583: Reconfigurable Computing Systems**

(Cross-listed with CPR E). (3-0) Cr. 3.

*Prereq: Background in computer architecture, design, and organization*

Introduction to reconfigurable computing, FPGA technology and architectures, spatial computing architectures such as systolic and bit serial adaptive network architectures, static and dynamic rearrangeable interconnection architectures, processor architectures incorporating reconfigurability.

**COM S 586: Computer Network Architectures**

(3-0) Cr. 3.

*Prereq: COM S 511, COM S 552 or CPR E 489*

Design and implementation of computer communication networks: layered network architectures, local area networks, data link protocols, distributed routing, transport services, network programming interfaces, network applications, error control, flow/congestion control, interconnection of heterogeneous networks, TCP/IP, software-defined networking and network security.

**COM S 587: Network Programming, Applications, and Research Issues**

(Dual-listed with COM S 487). (3-0) Cr. 3.

*Prereq: Com S 352 or CPR E 489 or equivalent; for graduate credit: graduate standing or permission of instructor*

Programming paradigms for building distributed and networking applications, including multithreaded client-server programming, socket programming, distributed object frameworks and programming suites, and web computing and security. Introduction to some on-going research issues in distributed and networking applications, including peer-to-peer computing, multimedia communications, and mobile computing and networking. Written report and oral presentation required for graduate credit.

**COM S 590: Special Topics**

Cr. arr. Repeatable.

*Prereq: Permission of instructor*

Special Topics in Computer Science.

**COM S 592: Research Colloquia**

Cr. 1.

*Prereq: Graduate classification*

Attend Computer Science Research Colloquia. Written summary is required. Offered on a satisfactory-fail basis only.

**COM S 598: Graduate Internship**

Cr. R. Repeatable.

*Prereq: Graduate Classification*

Supervised internship working in professional settings appropriate to the student's degree program. Academic work under faculty supervision.

**COM S 599: Creative Component**

Cr. 1-3.

Creative component for nonthesis option of Master of Science degree. Offered on a satisfactory-fail basis only.

**Courses for graduate students:****COM S 610: Seminar**

Cr. arr.

Seminar in Computer Science. Offered on a satisfactory-fail basis only.

**COM S 611: Advanced Topics in Analysis of Algorithms**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 511, COM S 531*

Advanced algorithm analysis and design techniques. Topics include, but are not limited to, graph algorithms, geometric algorithms, approximation algorithms, fixed-parameter algorithms, randomized algorithms and advanced data structures. Content varies by semester.

**COM S 612: Distributed Algorithms**

(3-0) Cr. 3.

*Prereq: COM S 511 or COM S 531*

The theory of distributed computation. Algorithms, lower bounds and impossibility results. Fundamental problems including consensus, leader election, mutual exclusion and clock synchronization. Synchronous, asynchronous and partially synchronous distributed systems models. Shared memory and message passing systems. Fault-tolerance and randomization. Wait-free object simulations. Distributed shared memory. Special topics vary from year to year.

**COM S 626: Parallel Algorithms for Scientific Applications**

(Cross-listed with CPR E). (3-0) Cr. 3.

*Prereq: CPR E 526*

Algorithm design for high-performance computing. Parallel algorithms for multidimensional tree data structures, space-filling curves, random number generation, graph partitioning and load balancing. Applications to grid and particle-based methods and computational biology.

**COM S 631: Advanced Topics in Computational Complexity**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 531*

Advanced study in the quantitative theory of computation. Time and space complexity of algorithmic problems. The structure of P, NP, PH, PSPACE, and other complexity classes, especially with respect to resource-bounded reducibilities and complete problems. Complexity relative to auxiliary information, including oracle computation and relativized classes, randomized algorithms, advice machines, Boolean circuits. Kolmogorov complexity and randomness. Novel models of computation emerging in a rapidly changing field.

**COM S 633: Advanced Topics in Computational Randomness**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 531*

Advanced study of the role of randomness in computation. Randomized algorithms, derandomization, and probabilistic complexity classes. Kolmogorov complexity, algorithmic information theory, and algorithmic randomness. Applications chosen from cryptography, interactive proof systems, computational learning, lower bound arguments, mathematical logic, and the organization of complex systems. Novel models of computation emerging in a rapidly changing field.

**COM S 634: Theory of Games, Knowledge and Uncertainty**

(3-0) Cr. 3.

*Prereq: COM S 230*

Fundamentals of Game Theory: individual decision making, strategic and extensive games, mixed strategies, backward induction, Nash and other equilibrium concepts. Discussion of Auctions and Bargaining. Repeated, Bayesian and evolutionary games. Interactive Epistemology: reasoning about knowledge in multiagent environment, properties of knowledge, agreements, and common knowledge. Reasoning about and representing uncertainty, probabilities, and beliefs. Uncertainty in multiagent environments. Aspects and applications of game theory, knowledge, and uncertainty in other areas, especially Artificial Intelligence and Economics, will be discussed.

**COM S 641: Advanced Topics in Programming Language Semantics**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 531, COM S 541*

Operational and other mathematical models of programming language semantics. Type systems and their soundness. Applications of semantics on areas such as program correctness, language design or translation.

**COM S 652: Advanced Topics in Distributed Operating Systems**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 552*

Concepts and techniques for network and distributed operating systems: communications protocols, processes and threads, name and object management, synchronization, consistency and replications for consistent distributed data, fault tolerance, protection and security, and distributed file systems. Research project.

**COM S 657: Advanced Topics in Computer Graphics**

(3-0) Cr. 3. Repeatable, maximum of 2 times.

*Prereq: COM S 228, I E 557/M E 557/CPR E 557/COM S 557*

Modern lighting models: Rendering Equation, Spherical Harmonics, Lafortune, Cook-Torrance. Non-polygonal primitives: volumes, points, particles. Textures: filtering, reflections creation. Graphics hardware: pipeline, performance issues, programmability in vertex and fragment path. Per-pixel lighting. Nonphotorealistic rendering. Radiosity; Ray tracing.

**COM S 661: Advanced Topics in Database Systems**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 461 or COM S 561*

Advanced topics chosen from the following: database design, data models, query systems, query optimization, incomplete information, logic and databases, multimedia databases; temporal, spatial and belief databases, semistructured data, concurrency control, parallel and distributed databases, information retrieval, data warehouses, wrappers, mediators, and data mining.

**COM S 665: Advanced Topics in Software Engineering**

Cr. 3. Repeatable, maximum of 6 credits. Alt. F., offered irregularly. Alt. S., offered irregularly.

*Prereq: COM S 511*

Advanced topics on software repository analysis, data mining and software engineering, software engineering for context-aware and situation-aware computing, distributed development, product lines, safety, security, and reliability, and traceability. Content varies by semester. Maximum 6 credits of COM S 665 may apply toward graduation.

**COM S 665A: Advanced Topics in Software Engineering: Foundations**

Cr. 3. Repeatable, maximum of 6 credits. Alt. F., offered irregularly. Alt. S., offered irregularly.

*Prereq: COM S 511*

Advanced topics on theoretical and technical foundations in Software Engineering. Content varies by semester. Maximum 6 credits of COM S 665 may apply toward graduation.

**COM S 665B: Advanced Topics in Software Engineering: Empirical**

Cr. 3. Repeatable, maximum of 6 credits.

*Prereq: COM S 511*

Advanced topics on empirical studies on human factors and other software engineering topics. Content varies by semester. Maximum 6 credits of COM S 665 may apply toward graduation.

**COM S 672: Advanced Topics in Computational Intelligence**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 572 or COM S 573 or COM S 472 or COM S 474*

Selected topics in probabilistic graphical models, causal inference, semantic web, information retrieval, natural language processing, knowledge representation and reasoning, deep learning, embedding, distributed learning, incremental learning, multi-task learning, multi-strategy learning, multi-relational learning, modeling the internet and the web, automated scientific discovery, neural and cognitive modeling. Advanced applications of artificial intelligence in bioinformatics, distributed systems, natural language, multimedia data, decision making, robotics, and more.

**COM S 673: Advanced Topics in Computational Models of Learning**

(3-0) Cr. 3. Repeatable.

*Prereq: COM S 572 or COM S 573 or COM S 472 or COM S 474*

Advanced topics in machine learning. Selected topics in computational learning theory, Bayesian and information theoretic models (ML, MAP, MDL, MML), probabilistic graphical models, statistical relational learning, reinforcement learning, and deep learning.

**COM S 681: Advanced Topics in Computer Architecture**

(Cross-listed with CPR E). (3-0) Cr. 3. Alt. S., offered odd-numbered years.

*Prereq: CPR E 581. Repeatable with Instructor permission*

Current topics in computer architecture design and implementation.

Advanced pipelining, cache and memory design techniques. Interaction of algorithms with architecture models and implementations. Tradeoffs in architecture models and implementations.

**COM S 699: Research**

Cr. arr. Repeatable.

*Prereq: Approval of instructor*

Research. Offered on a satisfactory-fail basis only.