COMPUTING AND INFORMATION SCIENCE

ADMINISTRATION

Robert Constable, dean

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INTRODUCTION

Computing and Information Science (CIS) offers courses and programs campuswide in various academic disciplines in which computing is integral. It is home to the Department of Computer Science, the Department of Statistical Science, the program in Information Science, and interdisciplinary programs in computational biology, computational science and engineering, game design, and computing in the arts. The faculty members associated with CIS programs hold joint appointments with CIS and another Cornell academic unit.

Computing and Information Science is a rapidly changing area. Please consult the CIS web site, www.cis.cornell.edu, for the most current news of programs and courses, or visit the CIS undergraduate office in 303 Upson Hall.

ACADEMIC PROGRAMS

Computing and Information Science offers the following academic programs through its corresponding colleges. See the departmental listings for details of the programs.

Computational Biology

Undergraduate students interested in computational biology can pursue study in the field through a variety of academic programs within their major. Programs in computational biology are available to students majoring in biology, biological statistics and computational biology (BSCB), and mathematics. Students majoring in computer science should review the vector in computational science.

A concentration in computational biology is available to biological sciences majors in the College of Agriculture and Life Sciences and the College of Arts and Sciences and is coordinated by the Office of Undergraduate Biology. It provides core training in biology and the supporting physical and computer sciences.

The concentration in statistical genomics is offered by the Department of Biological Statistics and Computational Biology to students enrolled in the College of Agriculture and Life Sciences. It provides training in statistics, biology, and computer science. It is designed for students who want to emphasize statistics and bioinformatics.

The concentration in mathematical biology is offered by the Department of Mathematics and is open to students enrolled in the College of Arts and Sciences. It provides training in mathematics, biology, and computer science. It is designed for students who want to emphasize mathematics.

Computational Science and Engineering

The CIS program in Computational Science and Engineering (CSE) spans several dozen departments and research areas. The field is application-driven and involves a mix of applied mathematics, numerical analysis, and computer science. Numerous courses are taught throughout the university. Go to www.cis.cornell.edu/cse for a list of courses and associated faculty members.

Computer Science

All CIS programs have connections to computer science, the study of computation in all of its forms. The curriculum covers the theory of algorithms and computing and its many applications in science, engineering, and business. Students learn the algorithmic method of thinking and how to bring it to bear on a wide range of problems. They also study the elements of computing and information technology such as system design, problem specification, programming, system analysis and evaluation, and complex modeling. Research areas include artificial intelligence, bioinformatics, computational logic, computer architecture, computer graphics, computer vision, computing systems, databases and digital libraries, natural language processing, networks, programming languages and compilation, scientific computing, security, and theory of algorithms.

The Department of Computer Science offers the computer science major to students in the College of Arts and Sciences and the College of Engineering, the computer science minor to students across colleges, and the Master of Engineering (M.Eng.) degree in computer science.

Computing in the Arts

An undergraduate minor in Computing in the Arts offers students opportunities to use computers to realize works of art, to study the perception of artistic phenomena, and to think about new, computer-influenced paradigms and metaphors for the experiences of making and appreciating art. Faculty from several departments across the university offer courses toward the minor, drawing on disciplines in the arts, computing, the social sciences, the humanities, and the physical sciences. Tracks are available for students pursuing this minor in: computer science, music, psychology, dance, and film. This minor is offered through the College of Arts and Sciences and coordinated by the Department of Computer Science. Students across colleges are eligible to pursue this program of study.

Game Design

The undeniable popularity of games draws the attention of academia, industry, and even the government on areas of design, development, and social impact. The game industry, like the film industry, is an unmistakable force in entertainment. Like filmmaking, game design can thrive and evolve only with the support of a strong academic foundation. The Game Design minor is offered by the Department of Computer Science for students who anticipate that game design will have a prominent role to play in their academic and professional career. Visit www.cs.cornell.edu/degreeprogs/ugrad/CSMinor/GameDesignMinor/index.htm for minor requirements. To learn about the Game Design Initiative at Cornell (GDIAC), visit gdiac.cis.cornell.edu. Students across colleges are eligible to pursue the Game Design minor.

Information Science

The interdisciplinary program Information Science studies the design and use of information systems in a social context. It integrates the study of three aspects of digital information systems. First, information science studies computing systems that provide people with information content; this study overlaps with parts of computer science, stressing the design, construction, and use of large information systems such as the World Wide Web and other global information resources. The second aspect of information science examines how people engage these information resources and how they can be integrated into everyday life. This area is also called "human-centered systems" because it is concerned with systems that hundreds of millions of people will use in daily life. The third aspect deals with understanding how information systems are situated in social, economic, and historical contexts. It explores the economic value of information, the legal constraints on systems, their social impact, and the cultural aspects of their construction. These are synergistic topics, and the next generation of scientists, scholars, business leaders, and government workers will need to understand them and how they relate.

Specific topics emphasized in the information science program include information networks; information discovery; knowledge organization; interaction design; interface design and evaluation; collaboration within and across groups, communities, organizations, and society; computational linguistics; computational techniques in the collection, archiving, and analysis of social science data; information privacy; methods of collecting, preserving, and distributing information; information system design; cognition and learning; social informatics; and cultural studies of computation.

The Information Science (IS) major is offered by the College of Agriculture and Life Sciences and the College of Arts and Sciences. Students in the College of Engineering may major in Information

Science, Systems, and Technology (ISST), which is offered jointly by the Department of Computer Science and the School of Operations Research and Information Engineering. For details about the IS and ISST majors, please refer to the respective colleges.

The minor in information science is available to students in all undergraduate colleges. Go to www.infosci.cornell.edu/ugrad/concentrations.html for details.

Statistical Science

The university-wide Department of Statistical Science coordinates activities in statistics and probability at the undergraduate, graduate, and research levels.

The department comprises four groups: Biological Statistics in the Department of Biological Statistics and Computational Biology, Engineering Statistics in the School of Operations Research and Information Engineering, Mathematical Statistics and Probability in the Department of Mathematics, and Social Statistics in the Department of Social Statistics. The areas covered include, but are not limited to, agricultural statistics, biostatistics, economic and social statistics, epidemiology, manufacturing statistics, quality control and reliability, probability theory, sampling theory, statistical computing, statistical design, statistical theory, and stochastic processes and their applications.

The department offers an undergraduate major and minor in Biometry and Statistics through the Department of Biological Statistics and Computational Biology in the College of Agriculture and Life Sciences. It also offers a minor in Engineering Statistics through the School of Operations Research and Information Engineering in the College of Engineering. Undergraduate majors and minors are under development for other colleges. For information, contact the undergraduate coordinator, 301 Malott Hall, 255-8066.

The department offers a Master of Professional Studies (MPS) in applied statistics for students pursuing careers in business, industry, and government. The MPS program has three main components: a two-semester core course, STSCI 5010 and 5020, covering a wide range of statistical applications, computing, and consulting; an in-depth statistical analysis MPS project supported by the core course; and required course work, including a two-semester course sequence in mathematical probability and statistics, and elective course work selected from offerings in this and other departments at Cornell. The M.P.S. program offers two options: Statistical Analysis and Data-Centered Statistics. A third option, Bioinformatics, is under development.

Students interested in graduate study in statistics and probability can apply to the graduate field of statistics or to one of the other graduate fields of study that offer related course work. Students in the field of statistics plan their graduate programs with the assistance of their special committee. For detailed information on opportunities for graduate study, contact the director of graduate studies, 301 Malott Hall.

A statistical consulting service is offered by the faculty of DSS and the Cornell Statistical Consulting Unit (CSCU), www.cscu.cornell.edu.

THE INFORMATION SCIENCE MINOR

A minor in information science is available to students in the Colleges of Agriculture and Life Sciences; Architecture, Art, and Planning (available to Architecture and Planning students only); Arts and Sciences; Engineering; Human Ecology; and the Schools of Hotel Administration and Industrial and Labor Relations. Because of small differences in regulations between the colleges, the requirements may vary slightly, depending on a student's college and, in a few cases, a student's major. Students interested in pursuing the information science minor must initiate the process by sending an e-mail message with their name, college, year of study (e.g., second-semester sophomore), expected graduation date, and (intended) major to minor@infosci.cornell.edu. See www.infosci.cornell.edu/ugrad.html for the most up-to-date description of the minor and its requirements.

Information science is an interdisciplinary field covering all aspects of digital information. The program has three main areas: human-centered systems, social systems, and information systems. Human-centered systems studies the relationship between humans and information, drawing from human-computer interaction and cognitive science. Social systems examines information in its economic, legal, political, cultural, and social contexts. Information systems studies the computer science problems of representing, storing, manipulating, and using digital information.

The minor has been designed to ensure that students have substantial grounding in all three of these areas, as well as in statistics. To this end, the requirements for the undergraduate minor are as follows: All courses must be chosen from the course lists below. In addition, a letter grade of at least C is required; S–U courses are not allowed.

Note: Course credits from institutions other than Cornell may not be counted toward the IS minor. Engineering students must use ENGRD 2700 or CEE 3040. Hotel students must use HADM 2201.

- **Statistics:** one course.
- **Human-centered systems** (human-computer interaction and cognitive science): two courses (for all colleges except Engineering and Hotel); one course (Engineering and Hotel).
- **Social systems** (social, economic, political, cultural, and legal issues): one course.
- **Information systems** (primarily computer science): two courses for all colleges except Hotel. Hotel students need to take one course in this area. Engineering students may not use INFO 1300. CS 2110 may not be used by students who are required to take it for their major.
- **Elective:** one additional course from any component area. Hotel students must take three courses in this category, from the following: HADM 3374, HADM 4474, or AEM 3220. (Engineering students and all computer science majors must select a course from human-centered systems or social systems. Communication majors must select a course outside Communication. Students in other majors should check with their advisors to make sure there are no special departmental restrictions or requirements.)

Statistics

An introductory course that provides a working knowledge of basic probability and statistics and their application to analyzing data occurring in the real world.

Engineering students must take one of the following:

- ENGRD 2700 Basic Engineering Probability and Statistics
- CEE 3040 Uncertainty Analysis in Engineering

Hotel students must take:

- HADM 2201 Hospitality Quantitative Analysis

All other students can meet this requirement with any one of the following:

- MATH 1710 Statistical Theory and Application in the Real World
- STSCI 2010 Introductory Statistics
- AEM 2100 Introductory Statistics
- PAM 2100 Introduction to Statistics
- HADM 2201 Hospitality Quantitative Analysis
- ENGRD 2700 Basic Engineering Probability and Statistics
- BTRY 3010 Statistical Methods I
- SOC 3010 Evaluating Statistical Evidence
- CEE 3040 Uncertainty Analysis in Engineering
- ILRST 3120 Applied Regression Methods
- ECON 3190 Introduction to Statistics and Probability
- PSYCH 3500 Statistics and Research Design

Human-Centered Systems

- COGST 1101 Introduction to Cognitive Science
- PSYCH 2050 Perception
- INFO 2140 Cognitive Psychology
- INFO 2450 Communication and Technology
- PSYCH 2800 Introduction to Social Psychology
- PSYCH 3420 Human Perception: Applications to Computer Graphics, Art, and Visual Display
- INFO 3400 Psychology of Social Computing
- INFO 3450 Human-Computer Interaction Design
- PSYCH 3470 Psychology of Visual Communications
- INFO 3650 Technology and Collaboration
- PSYCH 3800 Social Cognition
- PSYCH 4160 Modeling Perception and Cognition
- INFO 4400 Advanced Human-Computer Interaction Design
- INFO 4450 Seminar in Computer-Mediated Communication

- INFO 4500 Language and Technology
- DEA 4700 Applied Ergonomic Methods

Social Systems

- INFO 2040 Networks
- STS 2501 Technology in Society
- INFO 2921 Inventing an Information Society
- ECON 3010 Microeconomics*
- SOC 3040 Social Networks and Social Processes
- ECON 3130 Intermediate Microeconomic Theory*
- INFO 3200 New Media and Society*
- AEM 3220 Internet Strategy
- INFO 3490 Media Technologies
- INFO 3551 Computers: From the 17th Century to the Dotcom Boom
- INFO 3561 Computing Cultures
- INFO 3660 History and Theory of Digital Art
- ECON 3680 Game Theory*
- INFO 3871 The Automatic Lifestyle: Consumer Culture and Technology
- STS 4111 Knowledge, Technology, and Property
- INFO 4144 Responsive Environments
- SOC 4150 Internet and Society*
- ECON 4190 Economic Decisions Under Uncertainty
- COMM 4280 Communication Law
- INFO 4290 Copyright in the Digital Age
- ORIE 4350 Introduction to Game Theory*
- INFO 4470 Social and Economic Data
- HADM 4489 The Law of the Internet and E-Commerce
- ECON 4760 Decision Theory I
- ECON 4770 Decision Theory II
- INFO 4850 Computational Methods for Complex Networks
- INFO 5150 Culture, Law, and Politics of the Internet

*Only one of ECON 3010 and 3130 can be taken for IS credit. Only one of ORIE 4350 and ECON 3680 can be taken for IS credit. Only one of INFO 3220 and SOC 4150 may be taken for IS credit.

Information Systems

- INFO 1300 Introductory Design and Programming for the Web

Note: INFO 1301 and 1302 (no longer offered) may count together in place of INFO 1300.

- CS 2110 Object-Oriented Programming and Data Structures*
- INFO 2300 Intermediate Design and Programming for the Web*
- CIS 3000 Introduction to Computer Game Design
- INFO 3300 Data-Driven Web Applications
- INFO 4300 Information Retrieval
- INFO 4302 Web Information Systems
- CS 4320 Introduction to Database Systems
- LING 4424 Computational Linguistics
- LING 4474 Introduction to Natural Language Processing
- CS 4620 Introduction to Computer Graphics
- CS 4700 Foundations of Artificial Intelligence
- ORIE 4740 Statistical Data Mining I
- CS 4780 Machine Learning
- ORIE 4800 Information Technology
- ORIE 4810 Delivering OR Solutions with Information Technology
- ORIE 4850 Application of Operations Research and Game Theory to Information Technology
- CS 5150 Software Engineering
- INFO 5300 Architecture of Large-Scale Information Systems
- CS 5430 System Security
- ECE 5620 Fundamental Information Theory
- CS 5780 Empirical Methods in Machine Learning and Data Mining

*The following exceptions apply:

- INFO 1300: Engineering students and Computer Science majors may not use this course for the minor.
- INFO 2300: Computer Science majors may not use this course for the minor.
- CS 2110: Students for whom this is a required major course may not use it for the minor, e.g., Computer Science or Operations Research and Information Engineering majors.

COMPUTING AND INFORMATION SCIENCE (CIS) COURSES

CIS 1121 Introduction to MATLAB (also EAS 1121)

Fall, spring. 2 credits. Corequisite: MATH 1110, 1910, or equivalent. No programming experience assumed.

Introduction to elementary computer programming concepts using MATLAB. Topics include problem analysis, development of algorithms, selection, iteration, functions, and arrays. Examples and assignments are chosen to build an appreciation for computational science. The goal is for each student to develop a facility with MATLAB that will be useful in other courses whenever there is a need for computer problem solving or visualization.

CIS 1610 Computing in the Arts (also CS/ENGRI 1610, DANCE 1540, FILM 1750, MUSIC 1465, PSYCH 1650)

Fall. 3 credits.

For description, see CS 1610.

CIS 1620 Visual Imaging in the Electronic Age (also ARCH 3702, ART 1700, CS/ENGRI 1620)

Fall. 3 credits.

For description, see ART 1700.

CIS 3000 Introduction to Computer Game Design

Spring. 4 credits. Prerequisites: students must satisfy at least one of the following, according to their area of interest (art, music, or programming): Art: ART 2501 or equivalent; Music: CS 111x or INFO 1301–1302, MUSIC 1421 or equivalent; Programming: CS/ENGRD 2110 or equivalent.

Investigates the theory and practice of developing computer games from a blend of technical, aesthetic, and cultural perspectives. Technical aspects of game architecture include software engineering, artificial intelligence, game physics, computer graphics, and networking. Aesthetic and cultural aspects of design include art and modeling, sound and music, history of games, genre analysis, role of violence, gender issues in games, game balance, and careers in the industry. Programmers, artists, and musicians collaborate to produce an original computer game.

CIS 4002 Advanced Projects in Game Design

Fall. 3 credits. Prerequisites: CIS 3000 or permission of instructor.

Project-based follow-up course to CIS 3000. Students work in a multidisciplinary team to develop an original computer game or an application that explores innovative game technology. Students have the goal of submitting their work to a contest or conference. Grading is based on completion of project plans and documentation, teamwork, presentations and demonstrations, class participation, and quality of final projects. Instructional meetings are arranged based on student and instructor schedules.

CIS 4205 Effective Use of High-Performance Computing

Spring, usually weeks 1–7. 2 credits. Prerequisites: proficiency in C, C++, Fortran, or Fortran 90.

A hands-on introduction to high-performance computing (HPC) for graduate students or advanced undergraduate students who will use HPC as a tool in their work. Various HPC architectural platforms are described with a focus on computational clusters. Students learn how to identify and exploit parallelism in algorithms and legacy applications; how to measure parallel speedup and efficiency; and how to diagnose bottlenecks affecting performance. Parallel programming with MPI, OpenMP, and task-farming techniques (for web services and grid computing) is covered in depth. Examples and assignments are taken from typical application areas such as matrix and Monte Carlo computations. The goal of the class is for students to gain practical HPC experience for use in their specific fields of research.

CIS 4206 Introduction to Scripting in Python and Perl

Spring, usually weeks 1–8. 2 credits. Prerequisites: basic computer programming skills or permission of instructor.

Scientific computing today requires heterogeneous systems, software, and data to be used together in many different ways, based on desired results. Researchers commonly develop work-flows that control the processing of data and/or experiments from beginning to the desired results. The "glue" that often links the various stages of these work-flows is scripting languages. In

this course we explore scripting with two of the most popular scripting languages, Perl and Python, from the basics to specific types of functions/capabilities that are useful in the development and maintenance of scientific work-flows. Examples are provided for Microsoft Windows, Mac OS X and Red Hat Linux. Best-of-breed modules and tools are covered for each platform based on student interest.

CIS 4999 Independent Reading and Research
Fall, spring. 1–4 credits.
Independent reading and research for undergraduates.

CIS 5040 Applied Systems Engineering (also CEE 5040, SYSEN 5100, ECE/ ORIE 5120, MAE 5910)
Fall. 3 credits. Prerequisites: senior or graduate standing in engineering field; concurrent or recent (past two years) enrollment in group-based project with strong system design component approved by course instructor.
For description, see SYSEN 5100.

CIS 5050 Systems Analysis Architecture, Behavior, and Optimization (also CEE 5050, ECE/ ORIE 5130, MAE 5920, SYSEN 5200)
Spring. 3 credits. Prerequisite: Applied Systems Engineering (CEE 5240, ECE 5120, MAE 5910, ORIE 5120, or SYSEN 5100).
For description, see SYSEN 5200.

CIS 6229 Computational Methods for Nonlinear Systems (also PHYS 7682)
Fall. 4 credits. Enrollment may be limited.
For description, see PHYS 7682.

CIS 7999 Independent Research
Fall, spring. Variable credit. Prerequisite: permission of CIS faculty member.
Independent research or master of engineering project.

COMPUTER SCIENCE

The Department of Computer Science is affiliated with both the College of Arts and Sciences and the College of Engineering. Students in either college may major in computer science. The department is also part of CIS. Its courses are an integral part of CIS's several educational programs.

Consult the following web site for updates made after the publication of *Courses of Study*: www.cs.cornell.edu/courses/ listofcscourses/index.htm.

CS 1109 Fundamental Programming Concepts
Summer. 2 credits. Prerequisite: pre-freshman standing or permission of instructor. Credit may not be applied toward engineering degree. S–U grades only.
Designed for students who intend to take CS 111x but are not adequately prepared for it. Basic programming concepts and problem analysis are studied. An appropriate high-level programming language is used. Students with previous programming experience and students who do not intend to take CS 111x should not take this course.

CS 1110 Introduction to Computing Using Java
Fall, spring, summer. 4 credits. Assumes basic high school mathematics (no calculus) but no programming experience.
Programming and problem solving using Java. Emphasizes principles of software development, style, and testing. Topics include object-oriented concepts, procedures and functions, iteration, arrays, strings, algorithms, exceptions, GUIs (graphical user interfaces). Weekly labs provide guided practice on the computer, with staff present to help. Assignments use graphics and GUIs to help develop fluency and understanding.

CS 1112 Introduction to Computing Using MATLAB
Fall, spring. 4 credits. Corequisite: MATH 1110, 1910, or equivalent. Assumes student is comfortable with mathematics (at level of one semester of calculus) but has no prior programming experience.
Programming and problem solving using MATLAB. Emphasizes the systematic development of algorithms and programs. Topics include iteration, functions, arrays, and MATLAB graphics. Assignments are designed to build an appreciation for complexity, dimension, fuzzy data, inexact arithmetic, randomness, simulation, and the role of approximation.

CS 1114 Introduction to Computing Using MATLAB and Robotics
Spring. 4 credits. Prerequisite: some programming experience.
Honors-level introduction to computer science using camera-controlled robots using MATLAB. Emphasis is on modular design of programs and on fundamental algorithms. Extensive laboratory experiments with cameras and robots, including Sony Aibo. Example projects include controlling a robot by pointing a light stick and making a robot recognize simple colored objects.

CS 1130 Transition to Object-Oriented Programming
Fall, spring. 1 credit. Prerequisite: one course in programming. S–U grades only.
Introduction to object-oriented concepts using Java. Assumes programming knowledge in a language like MATLAB, C, C++, or Fortran. Students who have learned Java but were not exposed heavily to OO are welcome.

CS 1132 Transition to MATLAB
Fall, spring. 1 credit. Prerequisite: one course in programming. S–U grades only.
Introduction to MATLAB and scientific computing. Covers the MATLAB environment, assignment, conditionals, iteration, scripts, functions, arrays, scientific graphics, and vectorized computation. Assumes programming knowledge in a language like Java, C, C++, or Fortran.

CS 1300 Introductory Design and Programming for the Web (also INFO 1300)
Fall. 4 credits.
For description, see INFO 1300.

CS 1610 Computing in the Arts (also CIS/ENGRI 1610, DANCE 1540, FILM 1750, MUSIC 1465, PSYCH 1650)
Fall. 3 credits. Recommended: good comfort level with computers and some of the arts.
Over the centuries, artists in a wide variety of media have employed many approaches to the creative process, ranging from the philosophical to the mechanical to the virtual. This course unravels some of the mysteries going on inside software used for art and music. It looks at ways of breaking things apart and sampling and ways of putting things together and resynthesizing, and explores ideas for creation. This course does not teach software packages for creating art and music. The course complements ART 1701+ and MUSIC 1421+.

CS 1620 Visual Imaging in the Electronic Age (also ARCH 3702, ART 1700, CIS/ENGRI 1620)
Fall. 3 credits.
For description, see ART 1700.

CS 1710 Introduction to Cognitive Science (also COGST 1101, LING 1170, PHIL 1910, PSYCH 1102)
Fall, summer. 3 credits.
For description, see COGST 1101.

CS 2022 Introduction to C
Fall, spring, usually weeks 1–4. 1 credit. Prerequisite: one programming course or equivalent programming experience. Credit granted for both CS 2022 and 2024 only if 2022 taken first. S–U grades only.
Brief introduction to the C programming language and standard libraries. Unix accounts are made available for students wishing to use that system for projects, but familiarity with Unix is not required. Projects may be done using any modern implementation of C. CS 2024 (C++ Programming) includes much of the material covered in 2022. Students planning to take CS 2024 normally do not need to take 2022.

CS 2024 C++ Programming
Fall. 2 credits. Prerequisite: one programming course or equivalent programming experience. Students who plan to take CS 2022 and 2024 must take 2022 first. S–U grades only.
An intermediate introduction to the C++ programming language and the C/C++ standard libraries. Topics include basic statements, declarations, and types; stream I/O; user-defined classes and types; derived classes, inheritance, and object-oriented programming; exceptions and templates. Recommended for students who plan to take advanced courses in computer science that require familiarity with C++ or C. Students planning to take CS 2024 normally do not need to take CS 2022; 2024 includes most of the material taught in 2022.

CS 2026 Introduction to C#
Spring, usually weeks 5–8. 1 credit. Prerequisite: CS/ENGRD 2110 or equivalent experience. S–U grades only.
Introduces students to building applications in the .NET environment using the C# language.

CS 2042 Unix Tools
Fall, usually weeks 5–8. 1 credit. Prerequisite: one programming course or equivalent programming experience. S–U grades only.
Introduction to Unix, emphasizing tools for file management, communication, process control, managing the Unix environment, and rudimentary shell scripts. Projects assume no previous knowledge of Unix or expertise in any particular language.

CS 2044 Advanced UNIX Programming and Tools
Spring, usually weeks 5–8. 1 credit. Prerequisite: CS 2042 or equivalent. S–U grades only.
Focuses on Unix as a programming environment for people with a basic knowledge of Unix and experience programming in at least one language. Projects cover advanced shell scripts (sh, ksh, csh), Makefiles, programming and debugging tools for C and other languages, and more modern scripting languages such as Perl and Python. Students with little or no experience with Unix should take CS 2042 first.

CS 2110 Object-Oriented Programming and Data Structures (also ENGRD 2110)
Fall, spring, summer. 3 credits. Prerequisite: CS 1110, CS 1130, or CS 1113 or (CS 1112 if completed before fall 2007) or equivalent course in Java or C++.
Intermediate programming in a high-level language and introduction to computer science. Topics include program structure and organization, object-oriented programming (classes, objects, types, sub-typing), graphical user interfaces, algorithm analysis (asymptotic complexity, big "O" notation), recursion, data structures (lists, trees, stacks, queues, heaps, search trees, hash tables, graphs), simple graph algorithms. Java is the principal programming language.

CS 2300 Intermediate Design and Programming for the Web (also INFO 2300)
Spring. 3 credits. Prerequisite: CS 1300 strongly recommended. Must be taken before CS 3300.
For description, see INFO 2300.

CS 2800 Discrete Structures
Fall, spring. 3 credits. Pre- or corequisite: one programming course or permission of instructor.
Covers the mathematics that underlies most of computer science. Topics include mathematical induction; logical proof; propositional and predicate calculus; combinatorics and discrete mathematics; basic probability theory; basic number theory; sets, functions, and relations; partially ordered sets; and graphs. These topics are discussed in the context of applications to many areas of computer science, including game playing, the RSA cryptosystem, data mining, load balancing in distributed systems, properties of the Internet and World Wide Web, and web searching.

CS 2850 Networks (also ECON/INFO 2040, SOC 2090)
Spring. 4 credits. Prerequisites: none.
For description, see ECON 2040.

CS 3110 Data Structures and Functional Programming
Fall, spring. 4 credits. Prerequisite: CS 2110 and 2111 or equivalent programming experience. Pre- or corequisite: CS 2800. Should not be taken concurrently with CS 3410 or 3420.
Advanced programming course that emphasizes functional programming techniques and data structures. Programming topics include recursive and higher-order procedures, models of programming language evaluation and compilation, type systems, and polymorphism. Data structures and algorithms covered include graph algorithms, balanced trees, memory heaps, and garbage collection. Also covers techniques for analyzing program performance and correctness.

CS 3220 Introduction to Scientific Computation (also ENGRD 3220)
Spring, summer. 3 credits. Prerequisites: CS 1112 or 1132 and MATH 2220, 2230, or 2940.
Introduction to elementary numerical analysis and scientific computation. Topics include interpolation, quadrature, linear and nonlinear equation solving, least-squares fitting, and ordinary differential equations. The MATLAB computing environment is used. Vectorization, efficiency, reliability, and stability are stressed. Includes special lectures on computational statistics.

CS 3300 Data-Driven Web Applications (also INFO 3300)
Spring. 3 credits. Prerequisite: CS/ENGRD 2110 and (CS 2300 or permission of instructor). CS majors may use only one of the following toward their degree: CS/INFO 3300 or CS 4321.
For description, see INFO 3300.

CS 3410 Systems Programming
Spring. 4 credits. Prerequisite: CS 2110 or equivalent programming experience. Should not be taken concurrently with CS 3110.
Introduction to systems programming, computer organization, and the hardware/software interface. Topics include representation of information, machine and assembly languages, processor organization, memory management, input/output mechanisms, and basic network programming. Also covered are techniques for analyzing program performance and optimization

CS 3420 Computer Organization (also ECE 3140)
Spring. 4 credits. Prerequisite: CS 2110 or ENGRD 2300. Should not be taken concurrently with CS 3110.
For description, see ECE 3140.

CS 3740 Computational Linguistics (also COGST 4240, LING 4424)
Fall. 4 credits. Recommended: CS 2042.
For description, see LING 4424.

CS 3810 Introduction to Theory of Computing
Fall, summer. 3 credits. Prerequisite: CS 2800 or permission of instructor.
Introduction to the modern theory of computing: automata theory, formal languages, and effective computability.

CS 4120 Introduction to Compilers
Fall. 3 credits. Prerequisites: CS 3110 or permission of instructor and CS 3410 or 3420. Corequisite: CS 4121.
Introduction to the specification and implementation of modern compilers. Topics include lexical scanning, parsing, type checking, code generation and translation, an introduction to optimization, and the implementation of modern programming languages.

CS 4121 Practicum in Compilers
Fall. 2 credits. Corequisite: CS 4120.
Compiler implementation project related to CS 4120.

CS 4210 Numerical Analysis and Differential Equations (also MATH 4250)
Fall. 4 credits. Prerequisites: MATH 2210 or 2940 or equivalent, one additional mathematics course numbered 3000 or above, and knowledge of programming.
For description, see MATH 4250.

CS 4220 Numerical Analysis: Linear and Nonlinear Problems (also MATH 4260)
Spring. 4 credits. Prerequisites: MATH 2210 or 2940 or equivalent, one additional mathematics course numbered 3000 or above, and knowledge of programming.
Introduction to the fundamentals of numerical linear algebra: direct and iterative methods for linear systems, eigenvalue problems, singular value decomposition. In the second half of the course, the above are used to build iterative methods for nonlinear systems and for multivariate optimization. Strong emphasis is placed on understanding the advantages, disadvantages, and limits of applicability for all the covered techniques. Computer programming is required to test the theoretical concepts throughout the course.

CS 4300 Information Retrieval (also INFO 4300)
Fall. 3 credits. Prerequisite: CS 2110 or equivalent.
For description, see INFO 4300.

CS 4302 Web Information Systems (also INFO 4302)
Spring. 3 credits. Prerequisites: CS 2110 and some familiarity with web site technology.
For description, see INFO 4302.

CS 4320 Introduction to Database Systems
Fall. 3 credits. Prerequisites: CS 3110 (or CS 2110, 2111, and permission of instructor).
Introduction to modern database systems. Concepts covered include storage structures, access methods, query languages, query processing and optimization, transaction management, recovery, database design, XML, and XQuery. The course focuses on the design and internals of modern database systems.

CS 4321 Practicum in Database Systems
Fall. 2 credits. Pre- or corequisite: CS 4320. CS majors may use only one of the following toward their degree: CS/INFO 3300 or CS 4321.
Students build part of a real database system in C++.

CS 4410 Operating Systems
Fall. 3 credits. Prerequisite: CS 3410 or 3420.
Introduction to the logical design of systems programs, with emphasis on multiprogrammed operating systems. Topics include process synchronization, deadlock, memory management, input-output methods, information sharing, protection and security, and file systems. The impact of network and distributed computing environments on operating systems is also discussed.

CS 4411 Practicum in Operating Systems
Fall. 2 credits. Corequisite: CS 4410.
Studies the practical aspects of operating systems through the design and implementation of an operating system kernel that supports multiprogramming, virtual memory, and various input-output devices. All the programming for the project is in a high-level language.

CS 4420 Computer Architecture (also ECE 4750)
Fall. 4 credits. Prerequisites: ENGRD 2300 and CS 3420/ECE 3140.
For description, see ECE 4750.

CS 4620 Introduction to Computer Graphics (also ARCH 3704)
Fall. 3 credits. Prerequisite: CS/ENGRD 2110.
Introduction to the principles of computer graphics in two and three dimensions. Topics include digital images, filtering and anti-aliasing, 2-D and 3-D affine geometry, ray tracing, perspective and 3-D viewing, the graphics pipeline, curves and surfaces, and human visual perception. Homework assignments require some Java programming. May be taken with or without concurrent enrollment in CS 4621.

CS 4621 Computer Graphics Practicum
Fall. 2 credits. Pre- or corequisite: CS 4620.
Provides CS 4620 students with hands-on experience in computer graphics programming on modern graphics hardware. A semester-long project involves building a substantial interactive 3D system. The course uses Java and OpenGL for code development.

CS 4700 Foundations of Artificial Intelligence
Fall. 3 credits. Prerequisites: CS/ENGRD 2110 and CS 2800 (or equivalent).
Challenging introduction to the major subareas and current research directions in artificial intelligence. Topics include knowledge representation, heuristic search, problem solving, natural-language processing, game-playing, logic and deduction, planning, and machine learning.

CS 4701 Practicum in Artificial Intelligence
Fall. 2 credits. Pre- or corequisite: CS 4700.
Project portion of CS 4700. Topics include knowledge representation systems, search procedures, game-playing, automated reasoning, concept learning, reinforcement learning, neural nets, genetics algorithms, planning, and truth maintenance.

CS 4740 Introduction to Natural Language Processing (also COGST 4740, LING 4474)
Spring. 4 credits. Prerequisite: CS 2110.
Computationally oriented introduction to natural language processing, the goal of which is to enable computers to use human languages as input, output, or both. Possible topics include parsing, grammar induction, information retrieval, and machine translation.

CS 4780 Machine Learning
Spring. 4 credits. Prerequisites: CS 2100, CS 2800, or basic probability theory and basic knowledge of linear algebra.
Machine learning is concerned with the question of how to make computers learn from experience. The ability to learn is not only central to most aspects of intelligent behavior, but machine learning techniques have become key components of many software systems. For example, machine learning techniques are used to create spam filters, to analyze customer purchase data, and to explore new domains of science. This course introduces the fundamental set of techniques and algorithms that constitute machine learning as of today, including classification methods like decision trees and support vector machines, parametric Bayesian learning and hidden Markov models, as well as unsupervised learning and reinforcement learning. The course discusses algorithms and methods and provides an introduction to the theory of machine learning.

[CS 4782 Probabilistic Graphical Models (also BTRY 4790)
Fall. 4 credits. Prerequisites: probability theory (BTRY 4080 or equivalent), programming and data structures (CS 2110 or equivalent); course in statistical methods recommended but not required (BTRY 4090 or equivalent). Next offered 2010–2011.
For description, see BTRY 4790.]

CS 4812 Quantum Computation (also PHYS 4481/7681)
Spring. 2 credits. Prerequisite: familiarity with theory of vector spaces over complex numbers.
For description, see PHYS 4481.

CS 4820 Introduction to Analysis of Algorithms
Spring, summer. 4 credits. Prerequisites: CS 2800 and 3110.
Develops techniques used in the design and analysis of algorithms, with an emphasis on problems arising in computing applications. Example applications are drawn from systems and networks, artificial intelligence, computer vision, data mining, and computational biology. This course covers four major algorithm design techniques (greedy algorithms, divide-and-conquer, dynamic programming, and network flow), computability theory focusing on undecidability, computational complexity focusing on NP-completeness, and algorithmic techniques for intractable problems (including identification of structured special cases, approximation algorithms, and local search heuristics).

[CS 4830 Introduction to Cryptography
Fall. 4 credits. Prerequisites: CS 2800 (or equivalent), mathematical maturity, or permission of instructor. Next offered 2010–2011.
Introductory course in cryptography. Topics include one-way functions, encryption, digital signatures, pseudo-random number generation, zero-knowledge and basic protocols. Emphasizes fundamental notions and constructions with proofs or security based on precise definitions and assumptions.]

CS 4850 Mathematical Foundations for the Information Age
Spring. 4 credits. Prerequisite: mathematical maturity.
Covers the mathematical foundation underlying modeling and searching of the web and other complex networks, discovering trends, data mining, and making recommendations based on user behavior. Topics include random graphs; tail bounds; branching processes; spectral analysis; clustering; learning mixtures of distributions; extracting information from large, high dimensional, and noisy data; VC dimension; latent semantic indexing; and collaborative filtering.

CS 4860 Applied Logic (also MATH 4860)
Fall. 4 credits. Prerequisites: MATH 2220 or 2940, CS 2800 or equivalent (e.g., MATH 3320, 4320, 4340, 4810), and some additional course in mathematics or theoretical computer science.
Propositional and predicate logic, compactness and completeness by tableaux, natural deduction, and resolution. Equational logic. Herbrand Universes and unification. Rewrite rules and equational logic, Knuth-Bendix method, and the congruence-closure algorithm and lambda-calculus reduction strategies. Topics in Prolog, LISP, ML, or Nuprl. Applications to expert systems and program verification.

CS 4999 Independent Reading and Research
Fall, spring. 1–4 credits.
Independent reading and research for undergraduates.

CS 5150 Software Engineering
Fall. 4 credits. Prerequisite: CS 2110 or equivalent experience programming in Java or C++.
Introduction to the practical problems of specifying, designing, and building large, reliable software systems. Students work in teams on projects for real clients. This work includes a feasibility study, requirements analysis, object-oriented design, implementation, testing, and delivery to the client. Additional topics covered in lectures include professionalism, project management, and the legal framework for software development.

CS 5220 Applications of Parallel Computers
Spring. 4 credits. Prerequisites: course in numerical methods at level of CS 3220 or higher.
Models for parallel programming and survey of parallel machines. Existing parallel programming languages, vectorizing compilers, and parallel libraries and toolboxes. Techniques for data partitioning, synchronization, and load balancing. Performance tuning for serial and parallel codes. Applications to scientific problems. Work includes detailed study and programming of medium-sized representative applications.

CS 5300 The Architecture of Large-Scale Information Systems (also INFO 5300)
Spring. 4 credits. Prerequisite: CS/INFO 3300 or CS 4320.
For description, see INFO 5300.

CS 5410 Intermediate Computer Systems
Fall or spring. 4 credits. Prerequisite: CS 4410 or permission of instructor. Next offered fall 2009.
Focuses on practical issues in designing and implementing distributed software. Topics vary depending on instructor. Recent offerings have covered object-oriented software development methodologies and tools, distributed computing, fault-tolerant systems, and network operating systems or databases. Students undertake a substantial software project. Many students obtain additional project credit by co-registering in CS 4999 or 7999.

CS 5420 Parallel Computer Architecture (also ECE 5720)
Fall. 4 credits. Prerequisite: ECE 4750.
For description, see ECE 5720.

CS 5430 System Security
Fall or spring. 4 credits. Prerequisites: CS 4410 or 4450 and familiarity with JAVA, C, or C# programming languages. Next offered spring 2010.
Discusses security and survivability for computers and communications networks. Includes discussions of policy issues (e.g., the national debates on cryptography policy) as well as discussions of the technical alternatives for implementing the properties that comprise "trustworthiness" in a computing system. Covers mechanisms for authorization and authentication as well as cryptographic protocols.

CS 5620 Interactive Computer Graphics
Fall. 4 credits. Prerequisite: CS 4620.0.
Methods for interactive computer graphics, targeting applications including games, visualization, design, and immersive environments. Topics include programming graphics processing units (GPUs), shading models, advanced texturing, shadow algorithms, advanced lighting, hierarchical acceleration structures, and animation.

CS 5643 Physically Based Animation for Computer Graphics
Spring. 4 credits. Prerequisites: CS/ENGRD 3220 and/or CS 4620 or permission of instructor.
Modern computer animation and interactive digital entertainment are making increasingly sophisticated use of tools from scientific and engineering computing. This course introduces students to common physically based modeling techniques for animation of virtual characters, fluids and gases, rigid and deformable solids, and other systems. Aspects of interactive simulation and multi-sensory feedback are also discussed. A hands-on programming approach is taken, with an emphasis on small interactive computer programs.

CS 5722 Heuristic Methods for Optimization (also CEE 5290, ORIE 5340)
Fall. 3 or 4 credits. Prerequisites: CS/ENGRD 2110 or 3220 or CEE/ENGRD 3200, or graduate standing, or permission of instructor.
For description, see CEE 5290.

CS 6110 Advanced Programming Languages
Spring. 4 credits. Prerequisite: graduate standing or permission of instructor.
Study of programming paradigms: functional, imperative, concurrent, and logic programming. Models of programming languages, including the lambda calculus. Type systems, polymorphism, modules, and other object-oriented constructs. Program transformations, programming logic, and applications to programming methodology.

CS 6210 Matrix Computations
Fall. 4 credits. Prerequisites: MATH 4110 and 4310 or permission of instructor. Offered alternate years.
Stable and efficient algorithms for linear equations, least squares, and eigenvalue problems. Direct and iterative methods are considered. The MATLAB system is used extensively.

[CS 6240 Numerical Solution of Differential Equations
Spring. 4 credits. Prerequisites: exposure to numerical analysis (e.g., CS 4210 or 6210) and differential equations, and knowledge of MATLAB.]

CS 6320 Database Management Systems
Spring. 4 credits. Prerequisite: CS 4320 or permission of instructor.
Covers a variety of advanced issues ranging from transaction management to query processing to data mining. Involves extensive paper reading and discussion. Development of a term project with research content is required.

CS 6322 Advanced Database Systems
Fall. 4 credits.
Covers advanced topics in database systems and data mining. The exact set of topics changes with each offering of the course.

CS 6410 Advanced Systems
Fall or spring. 4 credits. Prerequisite: CS 4410 or permission of instructor. Offered fall 2009.
Advanced course in systems, emphasizing contemporary research in distributed systems. Topics may include communication protocols, consistency in distributed systems, fault-tolerance, knowledge and knowledge-based protocols, performance, scheduling, concurrency control, and authentication and security issues.

CS 6460 Peer-to-Peer Systems
Spring. 4 credits. Recommended: CS 6410.
Peer-to-peer (P2P) systems, in which clients not only consume resources but also provide their own resources for the use of other clients, have emerged as a new architectural paradigm in distributed computing. This course examines peer-to-peer systems and discusses existing and new applications. Students are expected to perform extensive reading on P2P and build a peer-to-peer system as part of this course.

CS 6464 Advanced Distributed Storage Systems
Spring. 4 credits. Prerequisite: CS 4410 or permission of instructor.
Broadly examines distributed storage systems in their many manifestations. Explores how to harness and maintain the collective storage capabilities in storage systems from global-scale enterprises and cloud computing to peer-to-peer, ad hoc, and home networks. Teaches abstractions, design, and implementation techniques that allow the building of the kind of scalable high-performance distributed systems that can deal with real-world workload. Students read recent research papers on server design, network programming, naming, various storage systems, security, and fault tolerance.

[CS 6620 Advanced Interactive Graphics
Fall or spring. 4 credits. Prerequisites: CS 4620 and 4621 or 5620 or permission of instructor. Next offered 2010–2011.
State-of-the-art techniques for high-quality rendering techniques used in simulation, games, and movies. Focus is on practical rendering algorithms for graphics applications.]

CS 6630 Realistic Image Synthesis
Fall or spring. 4 credits. Prerequisites: CS 4620 or equivalent and undergraduate-level understanding of algorithms, probability and statistics, vector calculus, and programming. Offered fall 2009.
Advanced course in realistic image synthesis, focusing on the computation of physically accurate images. Topics include radiometry; Monte Carlo methods, models for light reflection from surfaces and scattering in volumes, and algorithms for global illuminations.

[CS 6650 Computational Motion
Fall. 4 credits. Prerequisites: undergraduate-level understanding of algorithms, and some scientific computing. Offered alternate years; next offered 2010–2011.
Covers computational aspects of motion, broadly construed. Topics include the computer representation, modeling, analysis, and simulation of motion. Students implement several of the algorithms covered in the course and complete a final project.]

CS 6670 Computer Vision
Fall or spring. 4 credits. Prerequisites: undergraduate-level understanding of algorithms and MATH 2210 or equivalent. Offered fall 2009.
Introduction to computer vision, with an emphasis on discrete optimization algorithms and on applications in medical imaging. Topics include edge detection, image segmentation, stereopsis, motion and optical flow, active contours, and the Hausdorff distance. Students are required to implement several of the algorithms covered in the course and complete a final project.

CS 6700 Advanced Artificial Intelligence
Spring. 4 credits. Prerequisites: CS 4700 or permission of instructor.
Artificial intelligence (AI) provides many computational challenges. This course covers a variety of areas in AI, including knowledge representation, automated reasoning, learning, game-playing, and planning, with an emphasis on computational issues. Specific topics include stochastic reasoning and search procedures, properties of problem encodings, issues of syntax and semantics in knowledge representation, constraint satisfaction methods and search procedures, and critically constrained problems and their relation to phase-transition phenomena. In addition, connections between artificial intelligence and other fields, such as statistical physics, operations research, and cognitive science are explored.

CS 6740 Advanced Language Technologies (also INFO 6300)
Fall, spring. 3 credits. Prerequisite: permission of instructor. Neither CS 4300 nor CS 4740 are prerequisites.
Graduate-level introduction to technologies for the computational treatment of information in human-language form, covering modern natural-language processing (NLP) and/or information retrieval (IR). Possible topics include latent semantic analysis (LSI), clickthrough data for web search, language modeling, text categorization and clustering, information extraction, computational syntactic and semantic formalisms, grammar induction, and machine translation.

[CS 6764 Reasoning about Knowledge
Fall. 4 credits. Prerequisites: mathematical maturity and acquaintance with propositional logic. Next offered 2010–2011.
Knowledge plays a crucial role in distributed systems, game theory, and artificial intelligence. The course considers formal models of knowledge and applications in these areas.]

CS 6780 Advanced Topics in Machine Learning
Fall or spring. 4 credits. Prerequisites: CS 4780 or equivalent, or CS 5780 or equivalent, or permission of instructor. Offered fall 2009.
Extends and complements CS 4780 and 5780, giving in-depth coverage of new and advanced methods in machine learning. In particular, we connect to open research questions in machine learning, giving starting points for future work. The content of the course reflects an equal balance between learning theory and practical machine learning, making an emphasis on approaches with practical relevance. Topics include support vector machines, clustering, Bayes nets, boosting, model selection, learning orderings, and inductive transfer.

[CS 6782 Probabilistic Graphical Models (also BTRY 6790)
Fall. 4 credits. Prerequisites: probability theory (BTRY 4080 or equivalent), programming and data structures (CS 2110 or equivalent); a course in statistical methods is recommended but not required (BTRY 4090 or equivalent). Next offered 2010–2011.
For description, see BTRY 6790.]

[CS 6810 Theory of Computing
Fall or spring. 4 credits. Prerequisites: CS 3810 and CS 4820 or 6820 or permission of instructor. Next offered 2010–2011.
Advanced treatment of theory of computation, computational-complexity theory, and other topics in computing theory.]

CS 6820 Analysis of Algorithms
Fall. 4 credits. Prerequisite: CS 4820 or graduate standing.
Methodology for developing and analyzing efficient algorithms. Understanding the inherent complexity of natural problems via polynomial-time algorithms, advanced data structures, randomized algorithms, approximation algorithms, and NP-completeness. Additional topics may include algebraic and number theoretic algorithms, circuit lower bounds, online algorithms, or algorithmic game theory.

[CS 6822 Advanced Topics in Theory of Computing
Fall or spring. 4 credits. Prerequisite: CS 6810, 6820, or 6830 recommended, depending on the topic. Next offered 2010–2011.
An advanced study of current topics in the theory of computing. Topics may include algorithms, complexity, logic, cryptography, or theories of networks, information, and learning. Course may be repeated for credit.]

CS 6830 Cryptography
Fall. 4 credits. Prerequisites: general ease with algorithms and elementary probability theory, maturity with mathematical proofs (ability to read and write mathematical proofs).
Graduate introduction to cryptography. Topics include encryption, digital signatures, pseudo-random number generation, zero-knowledge, and basic protocols. Emphasizes fundamental concepts and proof techniques.

CS 6840 Algorithmic Game Theory
Fall or spring. 4 credits. Prerequisite: background in algorithms and graphs at level of CS 4820. No prior knowledge of game theory or economics assumed. Offered fall 2009.
Algorithmic game theory combines algorithmic thinking with game-theoretic or, more generally, economic concepts. This course focuses on problems arising from, and motivated by, the Internet and other decentralized computer networks. The most defining characteristic of the Internet is that it was not designed by a single central entity, but emerged from the complex interaction of many economic agents, such as network operators, service providers, designers, and users, in varying degrees of collaboration and competition. The course focuses on some of the many questions at the interface between algorithms and game theory that arise from this point of view. Topics include Nash equilibrium and general equilibrium, the price of anarchy, market equilibrium, social choice theory, mechanism design, and multicast pricing.

[CS 6850 The Structure of Information Networks (also INFO 6850)]

CS 6860 Logics of Programs
Spring. 4 credits. Prerequisites: CS 4810, 6810, and (MATH 4810 or CS/MATH 4860).
Topics in logics of programs and program verification. Possible topics include: Floyd/Hoare logic, modal logic, dynamic logic, temporal logic, process logic, automata on infinite objects and their relation to program logics, the Rabin tree theorem, the modal mu-calculus, games and alternating automata, applications to type inference, set constraints, Kleene algebra.

CS 7090 Computer Science Colloquium
Fall, spring. 1 credit. For staff, visitors, and graduate students interested in computer science. S–U grades only.
Weekly meeting for the discussion and study of important topics in the field.

CS 7190 Seminar in Programming Languages
Fall, spring. 1 credit. Prerequisite: CS 6110 or permission of instructor. S–U grades only.

CS 7192 Seminar in Programming Refinement Logics
Fall, spring. 4 credits. Prerequisite: permission of instructor.
Topics in programming logics, possibly including type theory, constructive logic, decision procedures, heuristic methods, extraction of code from proofs, and the design of proof-development and problem-solving systems.

CS 7320 Topics in Database Systems
Fall, spring. 4 credits. S–U grades only.

CS 7390 Database Seminar
Spring. 1 credit. Prerequisite: CS 6322 or permission of instructor. S–U grades only.

CS 7490 Systems Research Seminar
Fall, spring. 1 credit. S–U grades only.

CS 7690 Computer Graphics Seminar
Fall, spring. 3 credits.

[CS 7726 Evolutionary Computation and Design Automation (also MAE 6500)
Spring. 4 credits. Prerequisite: programming experience or permission of instructor. Next offered 2010–2011.
Seminar course in evolutionary algorithms and their application to optimization and open-ended computational design. Genetic algorithms, genetic programming, co-evolution, arms races and cooperation, developmental representations, learning, and symbiosis are covered. Topics include artificial life, evolutionary robotics, and applications in a variety of domains in science and engineering. Suitable for students interested in computational techniques for addressing open-ended design problems and in computational models of evolutionary discovery.]

CS 7790 Seminar in Artificial Intelligence
Fall, spring. 4 credits. Prerequisite: permission of instructor. S–U grades only.

CS 7794 Seminar in Natural Language Understanding
Fall, spring. 2 credits.
Informal weekly seminar in which current topics in natural language understanding and computational linguistics are discussed.

CS 7860 Introduction to Kleene Algebra
Spring. 4 credits. Prerequisites: CS 4810 and (CS 4860 or MATH 4810).
Kleene algebra is an algebraic system for describing and reasoning about sequentional processes.Topics will include some subset of the following: Model theory, including language, relational, and trace models; matrix algebras and automata as matrices; formal power series in noncommuting variables; Salomaa's completeness theorem and Redko's theorem; deductive completeness; related structures including Conway's S-algebras and closed semirings; ideal completion; PSPACE completeness of the equational theory; Kleene algebra with tests; guarded strings and automata on traces; reduction of the Hoare theory to the equational theory; program schematology; commutative Kleene algebra; Brzozowski derivatives and Taylor's theorem; algebraic closure and Parikh's theorem; applications in program verification; coalgebraic theory.

CS 7890 Seminar in Theory of Algorithms and Computing
Fall, spring. 4 credits. Prerequisite: permission of instructor. S–U grades only.

CS 7893 Cryptography Seminar
Fall, spring. 1 credit.
Seminar for discussing recent or classical papers in cryptography.

CS 7999 Independent Research
Fall, spring. Prerequisite: permission of a computer science advisor.
Independent research or master of engineering project.

CS 9999 Thesis Research
Fall, spring. Prerequisite: permission of a computer science advisor. S–U grades only.
Doctoral research.

INFORMATION SCIENCE (INFO)

INFO 1300 Introductory Design and Programming for the Web (also CS 1300)
Fall. 4 credits.
The World Wide Web is both a technology and a pervasive and powerful resource in our society and culture. To build functional and effective web sites, students need technical and design skills as well as analytical skills for understanding who is using the web, in what ways they are using it, and for what purposes. In this course, students develop skills in all three of these areas through the use of technologies such as XHTML, Cascading Stylesheets, and PHP. Students study how web sites are deployed and used, usability issues on the web, user-centered design, and methods for visual layout and information architecture. Through the web, this course provides an introduction to the interdisciplinary field of information science.

INFO 2040 Networks (also ECON 2040, SOC 2090)
Spring. 4 credits.
For description, see ECON 2040.

INFO 2140 Cognitive Psychology (also COGST/PSYCH 2140)
Spring. 4 credits. Limited to 175 students. Prerequisite: sophomore standing. Graduate students, see INFO 6140.
For description, see PSYCH 2140.

INFO 2300 Intermediate Design and Programming for the Web (also CS 2300)
Spring. 3 credits. Prerequisite: INFO 1300 strongly recommended. Must be taken before INFO 3300.
Web programming requires the cooperation of two machines: the one in front of the viewer (client) and the one delivering the content (server). INFO 1300 concentrates almost exclusively on the client side. The main emphasis in INFO 2300 is learning about server side processing. Students begin with a short overview of he PHP server-side scripting language, then look at interactions with databases, learning about querying both on paper and via SQL. Through a succession of projects, students learn how to apply this understanding to the creation of an interactive data-driven site via PHP and the MYSQL database. Also considered are technologies such as Javascript and Ajax; techniques to enhance security, privacy, reliability, and ways of incorporating other programs. Toward the end of the course, students are shown how these development tools are working. Design and usability issues are emphasized. A major component of the course is the creation of a substantial web site.

[INFO 2310 Topics in Web Programming and Design]

INFO 2450 Communication and Technology (also COMM 2450)
Fall, summer. 3 credits.
For description, see COMM 2450.

INFO 2921 Inventing an Information Society (also AMST/ECE/ENGRG 2980, HIST 2920, STS 2921)
Spring. 3 credits.
For description, see ENGRG 2980.

INFO 2950 Mathematical Methods for Information Science
Fall. 4 credits. Corequisite: MATH 2310 or equivalent.
Teaches basic mathematical methods for information science. Topics include graph theory, discrete probability, Bayesian methods, finite automata, Markov models, and hidden Markov models. Uses examples and applications from various areas of information science such as the structure of the web, genomics, natural language processing, and signal processing.

INFO 3200 New Media and Society (also COMM 3200)
Spring. 3 credits.
For description, see COMM 3200.

INFO 3300 Data-Driven Web Applications (also CS 3300)
Fall. 3 credits. Prerequisite: CS 2110 and (INFO 2300 or permission of instructor).
Introduces students to modern database systems and three-tier application development with a focus on building web-based applications using database systems. Concepts covered include the relational model, relational query languages, data modeling, normalization, database tuning, three-tier architectures, Internet data formats and query languages, server- and client-side technologies, and an introduction to web services. Students build a database-backed web site.

[INFO 3400 Psychology of Social Computing (also COMM 3400)
Fall. 3 credits. Prerequisite: INFO 2450. Next offered 2010–2011.
For description, see COMM 3400.]

INFO 3450 Human-Computer Interaction Design (also COMM 3450)
Fall. 3 credits. Prerequisite: INFO 2450. May be taken concurrently with INFO 2450.
For description, see COMM 3450.

[INFO 3490 Media Technologies (also COMM 3490, STS 3491)
Spring. 3 credits. Offered odd-numbered years. Next offered 2010–2011.
For description, see COMM 3490.]

[INFO 3551 Computers: From the 17th Century to the Dotcom Boom (also STS 3551)]

INFO 3561 Computing Cultures (also STS 3561)
Spring. 4 credits. No technical knowledge of computer use presumed or required. INFO 3551 and 3561 may be taken separately or in any order.
For description, see STS 3561.

INFO 3650 Technology and Collaboration (also COMM 3650)
Spring. 3 credits. Prerequisite: INFO 2450.
For description, see COMM 3650.

[INFO 3660 History and Theory of Digital Art (also ARTH 3650)
Fall. 4 credits. Next offered 2010–2011.
For description, see ARTH 3650.]

INFO 4290 Copyright in the Digital Age (also COMM 4290)
Fall. 3 credits. Offered odd-numbered years.
For description, see COMM 4290.

INFO 4300 Information Retrieval (also CS 4300)
Fall. 3 credits. Prerequisite: CS/ENGRD 2110 or equivalent.
Studies the methods used to search for and discover information in large-scale systems. The emphasis is on information retrieval applied to textual materials, but there is some discussion of other formats. The course includes techniques for searching, browsing, and filtering information and the use of classification systems and thesauruses. The techniques are illustrated with examples from web searching and digital libraries.

INFO 4302 Web Information Systems (also CS 4302)
Spring. 3 credits. Prerequisites: CS 2110 and some familiarity with web site technology.
Examines the architecture of web information systems such as distributed digital libraries and electronic publishing systems. Many of the topics presented are the subject of current research and development at Cornell, other universities, and in standards organizations such as the World Wide Web Consortium. Course content mixes exploration of current tools for building web information systems such as XML, XSLT, and RDF with broader concepts such as techniques for knowledge representation and description, object models for content representation, and legal and economic impacts of web information. A theme that runs throughout the course is the relationship between traditional information environments, exemplified by libraries, and the distributed information environment of the web.

[INFO 4350 Seminar on Applications of Information Science (also INFO 6350)]

INFO 4400 Advanced Human-Computer Interaction Design (also COMM 4400)
Spring. 3 credits. Prerequisites: INFO 2450.
For description, see COMM 4400.

INFO 4450 Seminar in Computer-Mediated Communication (also COMM 4450)
Spring. 3 credits. Prerequisite: INFO 2450.
For description, see COMM 4450.

INFO 4470 Social and Economic Data (also ILRLE 4470)
Fall. 4 credits. Prerequisites: calculus, IS statistics requirement, and one upper-level social science course, or permission of instructor.
Social and economic data drive decisions in public and private organizations, and quality decisions require quality data. This course focuses on data quality—conceptual fit, sampling and nonsampling error, timeliness, geographic detail, and dissemination—as well as legal and ethical issues in the data manufacturing process. Major emphasis is placed on public use microdata files of the U.S. Census Bureau and their role in the allocation of federal funds. These files include the Census of Population and Housing, Current Population Survey, American Housing Survey, Consumer Expenditure Survey, and American

Community Survey. The course is appropriate for upper-level undergraduate, professional master's, and doctoral students who will be users of data products, from the public and private sectors; and/or producers of data products for their organizations, working with existing data products from public and proprietary sources, as well as administrative or survey data collected by their organization.

INFO 4500 Language and Technology (also COMM 4500)
Spring. 3 credits. Prerequisite: INFO 2450 or permission of instructor.
For description, see COMM 4500.

INFO 4900 Independent Reading and Research
Fall, spring. 1–4 credits.
Independent reading and research for undergraduates.

INFO 4910 Teaching in Information Science, Systems, and Technology
Fall, spring. Variable credit.
Involves working as a T.A. in a course in the information science, systems, and technology major.

[INFO 5150 Culture, Law, and Politics of the Internet]

INFO 5300 The Architecture of Large-Scale Information Systems (also CS 5300)
Spring. 4 credits. Prerequisite: INFO/CS 3300 or CS 4320.
Deals with the architecture of large-scale information systems, with special emphasis on Internet-based systems. Topics include three-tier architectures, edge caches, distributed transaction management, web services, workflows, performance scalability, and high-availability architectures. The course includes a substantial project in the context of three-tier architectures, involving web servers, application servers, and database systems. Students study and use technologies such as Web Services, .Net, J2EE, ASPs, Servlets, XML, and SOAP.

INFO 6140 Cognitive Psychology (also COGST/PSYCH 6140)
Spring. 4 credits.
For description, see PSYCH 6140.

INFO 6300 Advanced Language Technologies (also CS 6740)
Fall or spring. 3 credits. Prerequisites: permission of instructor. Neither INFO/CS 4300 nor CS 4740 are prerequisites.
For description, see CS 6740 in CIS section.

INFO 6341 Information Technology in Sociocultural Context (also STS 6341)
Spring. 4 credits.
Analyzes information technology using historical, qualitative, and critical approaches. Discusses questions such as: In what ways is information technology—often portrayed as radically new—actually deeply historical? How do information technologies represent and intervene in debates and struggles among people, communities, and institutions? How is the design of information technology tools entangled in the realms of law, politics, and commerce? In what ways are the social consequences of information technologies produced as much by the claims we make about the technologies as about the raw functionality of the tools themselves? This course investigates these issues through the lenses of long-standing debates and current controversies.

[INFO 6350 Seminar on Applications of Information Science (also INFO 4390)]

INFO 6400 Human-Computer Interaction Design (also COMM 6400)
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor.
For description, see COMM 6400.

INFO 6450 Seminar in Computer-Mediated Communication (also COMM 6450)
Spring. 3 credits. Prerequisite: graduate standing or permission of instructor.
For description, see COMM 6450.

[INFO 6648 Speech Synthesis by Rule (also LING 6648)
Spring. 4 credits. Prerequisite: LING 4401, 4419, or permission of instructor. Next offered 2010–2011.
For description, see LING 6648.]

INFO 6500 Language and Technology (also COMM 6500)
Spring. 3 credits.
For description, see COMM 6500.

[INFO 6850 The Structure of Information Networks (also CS 6850)]

INFO 7050 Graduate Seminar
Fall, spring. 2 credits.
Graduate seminar on new research in the field of Information Science.

INFO 7090 IS Colloquium
Fall, spring. 1 credit.
For staff, visitors, and graduate students interested in information science.

INFO 7900 Independent Research
Fall, spring. Variable credit. Prerequisite: permission of an information science faculty member.
Independent research for M.Eng. students and pre–A exam Ph.D. students.

INFO 9900 Thesis Research
Fall, spring. Variable credit. Prerequisite: permission of an information science faculty member.
Thesis research for post–A exam Ph.D. students.

DEPARTMENT OF STATISTICAL SCIENCE

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M. T. Wells, chair (301 Malott Hall, 255-4388; R. L. Strawderman, director of graduate studies; J. A. Bunge, director of professional programs; J. Abowd, T. Apanosovich, J. Booth, C. Bustamante, T. DiCiccio, R. Durrett, E. Dynkin, T. Fine, X. Guo, Y. Hong, G. Hooker, J. T. G. Hwang, N. Kiefer, G. Lawler, P. Li, F. Molinari, M. Nielsen, M. Nussbaum, P. Protter, S. Resnick, D. Ruppert, G. Samorodnitsky, S. J. Schwager (undergraduate coordinator), B. Turnbull, P. Velleman

STSCI 2010 Introductory Statistics
Fall or spring. 4 credits.
Introduction to the basic concepts of probability, statistics and data analysis. Descriptive methods, normal theory models, and inferential procedures are considered. Topics include basic statistical designs, an introduction to probability, estimation, confidence intervals, tests of significance for a single population mean and proportion, the difference in two population means and proportions, ANOVA, multiple linear regression, and contingency tables.

STSCI 5010–5020 Applied Statistical Analysis
Two-semester core course for students in master of professional studies (M.P.S.) degree program in applied statistics in Department of Statistical Science. Prerequisite: enrollment in M.P.S. program.
Consists of a series of modules on various topics in applied statistics. Some modules include guest lectures from practitioners. Parallel with the course, students complete a yearlong, in-depth data analysis project.
Fall (STSCI 5010). 4 credits. Letter grades only.
Topics include but are not limited to: statistical computing systems, statistical software packages, data management, statistical graphics, and simulation methods and algorithms.
Spring (STSCI 5020). 4 credits. Letter grades only.
Topics include but are not limited to: sample surveys and questionnaire design, data sources, experimental design, and data mining.

STSCI 6000 Statistics Seminar
Fall and spring. 1 credit. Pre- or corequisite: BTRY 4090 or permission of instructor. S–U grades only.

FACULTY ROSTER

Computing and Information Science (CIS)

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Bailey, Graeme, Dept. of Computer Science; Computing in the Arts Program
Bala, Kavita, Dept. of Computer Science; Program of Computer Graphics
Bindel, David, Dept. of Computer Science
Birman, Kenneth, Dept. of Computer Science
Birnholtz, Jeremy, Information Science Program; Dept. of Communication
Blume, Lawrence, Information Science Program; Dept. of Economics
Bunge, John, Dept. of Statistical Science; School of Industrial and Labor Relations
Cardie, Claire, Dept. of Computer Science; Information Science Program
Constable, Robert, Dept. of Computer Science
Demers, Alan, Dept. of Computer Science
Easley, David, Information Science Program; Dept. of Economics
Ernste, Kevin, Computing in the Arts Program; Dept. of Music
Fan, Kit-Yee Daisy, Dept. of Computer Science
Francis, Paul, Dept. of Computer Science
Gay, Geri, Information Science Program; Dept. of Communication

Gehrke, Johannes, Dept. of Computer Science
Gillespie, Tarleton, Information Science Program; Dept. of Communication
Ginsparg, Paul, Information Science Program; Dept. of Physics
Gomes, Carla, Dept. of Computer Science; Dept. of Applied Economics and Management
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Gries, David, Dept. of Computer Science; College of Engineering
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Hancock, Jeff, Information Science Program; Dept. of Communication
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Hopcroft, John, Dept. of Computer Science
Huttenlocher, Daniel, Dept. of Computer Science; Information Science Program; Johnson Graduate School of Management
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Kedem, Klara, Dept. of Computer Science; Computational Biology Program
Kleinberg, Jon, Dept. of Computer Science; Computational Biology Program; Information Science Program
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Koch, Christoph, Dept. of Computer Science
Kozen, Dexter, Dept. of Computer Science
Kreitz, Christoph, Dept. of Computer Science
Lee, Lillian, Dept. of Computer Science; Information Science Program
Li, Ping, Dept. of Statistical Science
Lipson, Hod, Computing and Information Science Program; School of Mechanical and Aerospace Engineering
Macy, Michael, Information Science Program; Dept. of Sociology
Marschner, Steve, Dept. of Computer Science; Program of Computer Graphics
Myers, Andrew, Dept. of Computer Science
Nussbaum, Michael, Dept. of Statistical Science; Dept. of Mathematics
Pass, Rafael, Dept. of Computer Science
Rooth, Mats, Information Science Program; Dept. of Linguistics
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Selman, Bart, Dept. of Computer Science
Sengers, Phoebe, Information Science Program; Dept. of Science and Technology Studies
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Snavely, Noah, Dept. of Computer Science
Tardos, Eva, Dept. of Computer Science; Information Science Program
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Wells, Martin, Dept. of Statistical Science; Computational Biology Program
Williamson, David, Information Science Program; School of Operations Research and Industrial Engineering
Zabih, Ramin, Dept. of Computer Science