***Comparative Literature 399. Reading and Research**
Catalog Number: 2893
Svetlana Boym 1926 (on leave fall term), Joaquim-Francisco Coelho 7715, James Engell 8076 (on leave spring term), Luis M. Girón Negrón 3060 (on leave spring term), John T. Hamilton 3977, Barbara E. Johnson 7626, Despina Kakoudaki 3979 (on leave 2003-04), James L. Kugel 7575 (on leave fall term), Gregory Nagy 1423, Stephen Owen 7418 (on leave 2002-03), Judith Ryan 1135, Marc Shell 3176, Susan R. Suleiman 7234, William Mills Todd III 1634, and Ruth R. Wisse 3177 (on leave spring term)
Note: Candidates for the doctoral degree in Comparative Literature may pursue advanced studies under the individual supervision of these instructors. Permission to register for this course should be obtained from the instructor whose guidance is sought and from the Chairman of the Department.

Computer Science

Faculty of the Division of Engineering and Applied Sciences Offering Instruction in Computer Science

Roger W. Brockett, An Wang Professor of Electrical Engineering and Computer Science *(on leave fall term)*
David M. Brooks, Assistant Professor of Computer Science on the Gordon McKay Endowment
Mark S. Day, Lecturer on Computer Science *(fall term only)*
Steven J. Gortler, Associate Professor of Computer Science on the Gordon McKay Endowment *(Director of Undergraduate Studies)*
Barbara J. Grosz, Higgins Professor of Natural Sciences
H. T. Kung, William H. Gates Professor of Computer Science and Electrical Engineering *(on leave spring term)*
Henry H. Leitner, Senior Lecturer on Computer Science
Harry R. Lewis, Gordon McKay Professor of Computer Science and Dean of Harvard College
Michael D. Mitzenmacher, John L. Loeb Associate Professor of the Natural Sciences
Venkatesh Narayanamurti, John A. and Elizabeth S. Armstrong Professor of Engineering and Applied Sciences and Professor of Physics *(Dean of the Division of Engineering and Applied Sciences)*
John R. Nicol, Lecturer on Computer Science *(fall term only)*
Anthony G. Oettinger, Gordon McKay Professor of Applied Mathematics and Professor of Information Resources Policy
David C. Parkes, Assistant Professor of Computer Science on the Gordon McKay Endowment
Radia Perlman, Lecturer on Computer Science *(spring term only)*

Avrom J. Pfeffer, Assistant Professor of Computer Science on the Gordon McKay Endowment
Michael O. Rabin, Thomas J. Watson, Sr. Professor of Computer Science
Norman Ramsey, Assistant Professor of Computer Science on the Gordon McKay Endowment
Margo I. Seltzer, Gordon McKay Professor of Computer Science
Stuart M. Shieber, Harvard College Professor and James O. Welch, Jr. and Virginia B. Welch Professor of Computer Science
Michael D. Smith, Gordon McKay Professor of Computer Science and Electrical Engineering
Salil P. Vadhan, Assistant Professor of Computer Sciences on the Gordon McKay Endowment
Leslie G. Valiant, T. Jefferson Coolidge Professor of Computer Science and Applied Mathematics
Gu-Yeon Wei, Assistant Professor of Electrical Engineering on the Gordon McKay Endowment
Woodward Yang, Visiting Professor of Electrical Engineering and Computer Science

Other Faculty Offering Instruction in Computer Science

Marco Iansiti, David Sarnoff Professor of Business Administration *(Business School)*

The Division of Engineering and Applied Sciences offers undergraduate and graduate courses in Applied Mathematics, Applied Physics, Computer Science, Earth and Planetary Sciences, and Engineering Sciences. Recommended course programs at the undergraduate level may be obtained from the Academic Office, Pierce Hall 110. Division faculty also offer several courses in the section entitled General Education Electives.

Primarily for Undergraduates

For information concerning concentration in Computer Science please consult the Director of Undergraduate Studies or the Academic Office, Division of Engineering and Applied Sciences, Pierce Hall 110. The Applied Mathematics and Engineering Sciences sections of the catalog should be consulted for additional courses relevant to computer science. In addition, attention is called to the following courses in related fields: General Education 156, Linguistics 112a, 112b, Philosophy 144, Physics 123, Statistics 110, 111, 171.

Computer Science 50. Introduction to Computer Science I

Catalog Number: 4949

Michael D. Smith

Half course (fall term). M., W., F., at 10. EXAM GROUP: 3

Introduction to the intellectual enterprises of computer science. Algorithms: their design, specification, and analysis. Software development: problem decomposition, abstraction, data structures, implementation, debugging, testing. Architecture of computers: low-level data representation and instruction processing. Computer systems: programming languages, compilers, operating systems. Computers in the real world: networks, security and cryptography, artifical intelligence, social issues. Laboratory exercises include extensive programming in the C language and experimenting with and analyzing software systems.

Note: No previous computer experience required. This course, when taken for a letter grade, meets the Core area requirement for Quantitative Reasoning.

Computer Science 51. Introduction to Computer Science II

Catalog Number: 3411
Henry H. Leitner
Half course (spring term). Tu., Th., 1–2:30. EXAM GROUP: 15, 16
Abstract models for computational processes and their concrete realizations. Functional, imperative, object-oriented and event-driven styles of programming. The structure, interpretation and compilation of programming languages. State-space search, finite-state processes, formal logic, and syntactic and semantic formalisms as examples of useful abstractions. The engineering of complex software through procedural and data abstractions. Laboratory exercises using LISP, C++, and Java.
Prerequisite: Computer Science 50 or equivalent.

*Computer Science 91r. Supervised Reading and Research

Catalog Number: 0361
Steven J. Gortler
Half course (fall term; repeated spring term). Hours to be arranged.
In this course a student may undertake supervised individual study of advanced topics in computer science beyond those covered in regular courses, or may participate in a computer science research project. Students writing theses may enroll in this course while conducting their thesis research and writing. A student wishing to enroll in Computer Science 91r must be accepted by a faculty member who will supervise the course work and will specify the syllabus or project description. A form available in the Division of Engineering and Applied Sciences Academic Office, Pierce Hall 110, must be filled out with a description of the course work and the basis for its evaluation. This form must be signed by the student and the faculty supervisor and filed in the Academic Office by the date on which study cards are due. A written report of the work carried out in the course is ordinarily required by the beginning of the reading period.
Note: Ordinarily, at most two terms of Computer Science 91r may be taken for academic credit. May not be taken Pass/Fail. Students wishing more information about the range of suitable projects or faculty supervisors should consult the Director of Undergraduate Studies.

For Undergraduates and Graduates

Computer Science 120. Introduction to Cryptography

Catalog Number: 5911
Salil P. Vadhan
Half course (spring term). M., W., 1–2:30. EXAM GROUP: 6, 7
Algorithms to guarantee privacy and authenticity of data during communication and computation. Rigorous proofs of security based on precise definitions and assumptions. Topics may include one-way functions, private-key and public-key encryption, digital signatures, pseudorandom generators, higher-level protocols such as electronic cash, and the role of cryptography in network and systems security.
Prerequisite: Computer Science 121 or Computer Science 124.

Computer Science 121. Introduction to Formal Systems and Computation

Catalog Number: 0669
Harry R. Lewis

Half course (fall term). Tu., Th., 10–11:30. EXAM GROUP: 13
General introduction to formal systems and the theory of computation. Elementary treatment of automata, formal languages, computability, uncomputability, computational complexity, NP–completeness, and mathematical logic.

Computer Science 124. Data Structures and Algorithms
Catalog Number: 5207
Michael D. Mitzenmacher
Half course (spring term). Tu., Th., 11:30–1. EXAM GROUP: 13, 14
Design and analysis of efficient algorithms and data structures. Algorithm design methods, graph algorithms, approximation algorithms, and randomized algorithms are covered.
Prerequisite: Computer Science 51; some exposure to discrete applied mathematics, such as Applied Mathematics 106 or 107 or Computer Science 121 or Statistics 110, is helpful.

Computer Science 141. Computing Hardware
Catalog Number: 4357
Woodward Yang
Half course (fall term). M., W., F., at 12. EXAM GROUP: 5
Introduction to the design, structure, and operation of digital computers; logic circuits and digital electronics; computer arithmetic; computer architecture; and machine language programming. Consideration of the design interactions between hardware and software systems.
Prerequisite: Computer Science 50.

Computer Science 143. Computer Networks
Catalog Number: 6401
H. T. Kung
Half course (fall term). W., F., 2:30–4. EXAM GROUP: 7, 8
Architecture, design, and performance of computer networks. Topics include: the Internet protocols, local area networks, performance analysis, queueing theory, congestion control, multicast, quality of service, and network security. Programming exercises on protocol implementation.
Prerequisite: Computer Science 51.

[Computer Science 144r (formerly Computer Science 144). Networks Design Projects]
Catalog Number: 5415
H. T. Kung and Marco Iansiti (Business School)
Half course (spring term). W., F., 4–5:30. EXAM GROUP: 9
Cooperative design and development of a business model based on advanced business networking concepts in one of the three areas: optical networking, wireless networking, and inter-enterprise software applications. Students will work in 2- or 3-person teams. Student assignments will include weekly homework sets, a project proposal, and project reports and presentations. At the end of the class, all teams will defend their approaches and results in front of the class and invited guests.
Note: Expected to be given in 2003–04. Enrollment is limited. Preference will be given to upper class undergraduates or graduate students in computer science or in business. Offered jointly

with the Business School as 4560.
Prerequisite: Computer Science 143 or equivalent experience.

Computer Science 146. Computer Architecture
Catalog Number: 6520
David M. Brooks
Half course (fall term). Tu., Th., 2:30–4. EXAM GROUP: 16, 17
Review of the fundamental structures in modern processor design. Topics include computer organization, instruction set design, memory system design, pipelining, and other techniques to exploit parallelism. Emphasis on a quantitative evaluation of design alternatives and an understanding of timing issues.
Prerequisite: Computer Science 141.

Computer Science 148. Introduction to VLSI Design
Catalog Number: 1772 Enrollment: Limited to 16.
Gu-Yeon Wei
Half course (spring term). Tu., Th., 11:30–1. EXAM GROUP: 13, 14
Presentation of concepts and techniques for the design and fabrication of VLSI systems and integrated circuits. Topics include: basic semiconductor theory; MOS transistors; digital MOS circuit design; high-level modeling of VLSI systems; synthesis and place and route; memory and processor design; and testing of VLSI circuits and systems. Various CAD tools for design and simulation extensively used. Groups will build custom VLSI chips to be fabricated at an external VLSI foundry. Arrangements to test fabricated chips required.
Prerequisite: Engineering Sciences 50 or Physics 15b, and Computer Science 141, or permission of instructor.

Computer Science 152. Principles of Programming Languages
Catalog Number: 6841
Norman Ramsey
Half course (spring term). M., W., F., at 11. EXAM GROUP: 4
Intellectual tools needed to design, evaluate, and choose programming languages. Historical influences on language design. Case studies, reinforced by programming exercises. Advanced languages, abstraction mechanisms. Includes functional, object-oriented, and logic paradigms. Focuses on practice, but covers formal topics crucial for intellectual rigor: abstract syntax, lambda calculus, type systems, and dynamic semantics. Grounding sufficient to read professional literature.
Prerequisite: Computer Science 121. Students must have excellent programming skills, be comfortable with recursion, basic mathematical ideas and notations.

[Computer Science 153. Principles of Programming Language Compilation]
Catalog Number: 2842

Half course (fall term). Hours to be arranged.
Implementation of efficient interpreters and compilers for programming languages. Associated algorithms and pragmatic issues. Emphasizes practical applications including those outside of programming languages proper. Also shows relationships to programming-language theory and

design. Participants build a working compiler including lexical analysis, parsing, type checking, code generation, and register allocation. Exposure to run-time issues and optimization.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 121 and 152.

Computer Science 161. Operating Systems
Catalog Number: 4347
Margo I. Seltzer
Half course (spring term). Tu., Th., 1–2:30. EXAM GROUP: 15, 16
The fundamental principles of resource management and abstraction in modern operating systems. Control abstractions: thread, processes, scheduling synchronization. Storage abstractions: dynamic memory allocation, virtual memory, file system design. Communication abstractions: interprocess communication, networking. Case studies. Design and implementation of parts of a multiuser multitasking virtual-memory operating system.
Note: Open to students who achieved an honor grade (B- or better) in Computer Science 51 and who have experience developing large software systems.
Prerequisite: Computer Science 51.

Computer Science 175. Computer Graphics
Catalog Number: 3771
Steven J. Gortler
Half course (fall term). M., W., 4–5:30. EXAM GROUP: 9
The computational aspects of computer graphics. Two major themes are image rendering (viewing transformations, clipping, visible-surface processing, raster algorithms, reflection models, lighting models, surface shading, antialiasing, ray tracing, radiosity, and volume rendering) and scene modeling (modeling transformations, curves and surfaces, texture mapping, data-amplification techniques, constructive solid geometry, scalar- and vector-field data, and animation). Ancillary topics include color compression, image compression, image compositing, graphical user interfaces, and special machine architectures for computer graphics.
Prerequisite: Computer Science 51, Applied Mathematics 21b or Mathematics 21b.

Computer Science 181. Intelligent Machines: Perception, Learning, and Uncertainty
Catalog Number: 6454
Avrom J. Pfeffer
Half course (spring term). M., W., 2:30–4. EXAM GROUP: 7, 8
Introduction to artificial intelligence, focusing on problems of perception, machine learning and reasoning under uncertainty. Supervised learning algorithms. Neural networks and applications to character recognition. Statistical pattern recognition. Bayesian networks: representation, inference and learning. Hidden Markov models and applications to speech recognition. Markov decision processes and reinforcement learning.
Prerequisite: Computer Science 51 and Computer Science 121. Statistics 110 is recommended.

Computer Science 182. Intelligent Machines: Reasoning, Actions, and Plans
Catalog Number: 0134
David C. Parkes
Half course (fall term). M., W., 2:30–4. EXAM GROUP: 7, 8

Introduction to AI, focused on problems in reasoning about action and rational decision making. Search: constraint satisfaction; informed search and optimization; game playing. Knowledge representation. Partial-order planning: representations of actions; techniques for handling goal interactions. Bounded rationality, situated agents. Discussion of relevant work in philosophy, economics, and decision theory. Applications to language, robotics and multi-agent systems.
Prerequisite: Computer Science 51; Computer Science 121 (may be taken concurrently).

Computer Science 187. Computational Linguistics
Catalog Number: 0249 Enrollment: Limited to 20.
Stuart M. Shieber
Half course (fall term). F., 2:30–5:30. EXAM GROUP: 7, 8
Introduction to computational linguistics, the study of human language using the tools and techniques of computer science, with applications to a variety of natural-language-processing problems. Representing syntactic structure: context-free, augmented context-free, and trans-context-free grammars. Representing semantic structure: first-order and higher-order logics. Computing with syntactic and semantic representations: Prolog programming; parsing and generation algorithms. Low-level language processing with finite-state methods.
Prerequisite: Computer Science 121.

Primarily for Graduates

Computer Science 220r. Cryptography: Trust and Adversity
Catalog Number: 1637
Michael O. Rabin
Half course (fall term). Tu., Th., 11:30–1. EXAM GROUP: 13, 14
Topics in modern cryptography. Primality testing, finite fields, elliptic curves. Protocols: Public-key encryptions, digital signatures, key exchanges, zero-knowledge proofs, authentication oblivious transfer, secret sharing, proactive security, fair contract signing, distributed agreements. Foundations: Probablistic encryption and semantic security. Attacks and countermeasures: Non-malleability, plaintext awareness and proofs of plaintext knowledge. Absolutely secure encryptions. Prerequisites will be discussed in sections.

Computer Science 221. Computational Complexity
Catalog Number: 5812
Salil P. Vadhan
Half course (fall term). M., W., F., at 11. EXAM GROUP: 4
A quantitative theory of the resources needed for computing and the impediments to efficient computation. The models of computation considered include ones that are finite or infinite, deterministic, probabilistic, quantum or nondeterministic, discrete or algebraic, sequential or parallel.
Note: Expected to be given next in Spring 2004.
Prerequisite: Computer Science 121 or equivalent.

[Computer Science 222. Algorithms at the Ends of the Wire]
Catalog Number: 2493
Michael D. Mitzenmacher

Half course (fall term). Tu., Th., 2:30–4. EXAM GROUP: 16, 17
Covers topics related to what is done with information before and after it is sent across a network. Themes include compression, cryptography, coding, and information retrieval related to the World Wide Web. Theoretical aspects are emphasized, although current practice and recent advances are also a focus. Requires a major final project.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 124.

Computer Science 223. Probabilistic Analysis and Algorithms
Catalog Number: 4740
Michael D. Mitzenmacher
Half course (fall term). Tu., Th., 2:30–4. EXAM GROUP: 16, 17
Probabilistic techniques and tools for the design and analysis of algorithms. Reading of current research in the area will be required.
Prerequisite: Computer Science 124. Preferably additional probability, such as in Computer Science 226r, Statistics 110, or Mathematics 191.

[Computer Science 225. Pseudorandomness]
Catalog Number: 4869
Salil P. Vadhan
Half course (spring term). M., F., 1–2:30. EXAM GROUP: 6, 7
Efficiently generating objects that “look random” despite being constructed using little or no randomness. Connections and applications to computational complexity, cryptography, and combinatorics. Pseudorandom generators, randomness extractors, expander graphs, error-correcting codes, hash functions.
Note: Expected to be given in 2003–04.
Prerequisite: Exposure to randomized algorithms (as in Computer Science 124), computational complexity (as in Computer Science 121), and algebra (as in Applied Mathematics 106, Mathematics 123, or Computer Science 226r).

[Computer Science 226r. Efficient Algorithms]
Catalog Number: 1749
Michael O. Rabin
Half course (fall term). Tu., Th., 11:30–1. EXAM GROUP: 13, 14
A survey of important computer algorithms for numerical and data manipulation problems and their applications in actual computing situations. Topics include combinatorial algorithms, string matching, FFT and its applications, algebraic computations, randomized algorithms in algebra number theory and geometry, maximal flows, error correcting codes, public key cryptography, protocols for distributed systems, and parallel algorithms.
Note: Expected to be given in 2003–04.

Computer Science 228. Computational Learning Theory
Catalog Number: 0364
Leslie G. Valiant
Half course (spring term). Tu., Th., 2:30–4. EXAM GROUP: 16, 17
Possibilities of and limitations to performing learning by computational agents. Topics include

computational models, polynomial time learnability, learning from examples and learning from queries to oracles. Computational limitations. Statistical limitations. Applications to Boolean functions, automata and geometric functions. Learning algorithms for models of neural computation.
Prerequisite: Computer Science 121 or equivalent.

Computer Science 243. Network Security Protocols
Catalog Number: 9584
Radia Perlman
Half course (spring term). F., 2–5. EXAM GROUP: 7, 8
An in-depth investigation of network security. Mechanisms to reconcile often conflicting goals (e.g. anonymity vs. traceability). Covers both design options available and design decisions made in deployed systems, including Kerberos, IPsec, SSL, and X.509.
Prerequisite: Computer Science 50 and 124, or permission of the instructor.

[Computer Science 244r (formerly Computer Science 244). Advanced Networks Design Projects]
Catalog Number: 3018
H. T. Kung and Marco Iansiti (Business School)
Half course (spring term). W., F., 4–5:30. EXAM GROUP: 9
The contents and course requirements are similar to those of Computer Science 144r, with the exception that students enrolled in Computer Science 244r are expected to do substantial implementation of a subsystem related to their business plan. In addition, demonstration and documentation of the implementation are required.
Note: Expected to be given in 2003–04. Enrollment is limited. Preference will be given to upper class undergraduates or graduate students in computer science or in business who are proficient in computer programming or in business software. Offered jointly with the Business School as 4560.
Prerequisite: Computer Science 143 or equivalent experience.

***Computer Science 246. Advanced Computer Architecture**
Catalog Number: 0979
David M. Brooks
Half course (spring term). Hours to be arranged.
Discusses research papers on computer architecture with a special focus on the impact of technology trends (power, thermal, VLSI scaling, reliability) on high-performance computer systems. Considers traditional superscalar as well as embedded processors. Requires a major research project.
Prerequisite: Computer Science 146 or permission of the instructor.

Computer Science 251. Advanced Systems Programming
Catalog Number: 5566
Norman Ramsey
Half course (fall term). M., W., F., 1–2:30. EXAM GROUP: 6, 7
Case studies of classic problems in computer systems. Students read, understand, implement, and present each study. Develops deep understanding of programming techniques used in systems

research. Emphasizes programming, discussion, and presentation. Cases matched to student interests.
Prerequisite: One of the following: Computer Science 143, Computer Science 152, Computer Science 153, Computer Science 161, or Computer Science 175.

[Computer Science 252r. Advanced Topics in Programming Languages]
Catalog Number: 1986
Norman Ramsey
Half course (spring term). Hours to be arranged.
Advanced functional programming. Lazy evaluation, monads, monad comprehensions, the monadic approach to imperative features. Folds and unfolds. Functional reactive programming for graphics, robotics. Combinators for parsing and prettyprinting. Purely functional data structures. Type systems: polymorphism and overloading, type and constructor classes, higher-order kinds, polytypic programming. Implementation: heap profiling, match compilation.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 152 or permission of the instructor.

Computer Science 253r (formerly Computer Science 253). Advanced Topics in Programming Language Compilation
Catalog Number: 2901 Enrollment: Limited to 18. Preference given to graduate students or upper-class concentrators.
Michael D. Smith
Half course (spring term). Tu., Th., 11:30–1. EXAM GROUP: 13, 14
In-depth look at virtual machine (VM) technologies and the applications enabled by them. Special emphasis on the techniques for replication, translation, and optimization.
Prerequisite: Computer Science 153 or equivalent.

[Computer Science 254r. Programming Methodologies]
Catalog Number: 2767

Half course (spring term). Hours to be arranged.
Investigates program analysis, verification, and refinement; programming paradigms, including parallel and distributed; program development and maintenance environments. This year students will critique an experimental world-wide programming environment the instructors are developing: see www.deas.harvard.edu/courses/cs254r/2001.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 51 and 121, or equivalent.

[Computer Science 261. Research Topics in Operating Systems]
Catalog Number: 6706

Half course (fall term). Tu., Th., 4–5:30. EXAM GROUP: 18
A quantitative approach to operating system design and evaluation. Discussion of recent research including extensible operating system architectures, distributed systems, and performance analysis. Overview of research techniques and methodology.

Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 161, or equivalent.

[Computer Science 262. Introduction to Distributed Computing]
Catalog Number: 7949

Half course (spring term). Hours to be arranged.
Examination of the special problems associated with distributive computing, especially those associated with partial failure and intrinsic limitations on global knowledge. The course will emphasize the specification and implementation of high level protocols that allow computational entities to collaborate in the face of these problems. Causal ordering, event and RPC based systems, and security problems in distributed systems will be discussed.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 161 or permission of instructor.

Computer Science 265. Database Systems
Catalog Number: 4104
Margo I. Seltzer and Mark S. Day
Half course (fall term). Tu., Th., 1–2:30. EXAM GROUP: 15, 16
A research-oriented introduction to Database Management systems. First third covers database design, implementation, and use. Topics include: network, relational, and object oriented database models, system architectures, transaction processing, system implementation, and SQL. Remaining two-thirds address research literature surrounding database systems, including an historical perspective, the emergence of relational and object-oriented systems, concurrency control, and distributed systems. Students will be expected to undertake a final research project.
Prerequisite: Computer Science 51.

***Computer Science 277. Geometric Modeling in Computer Graphics**
Catalog Number: 3067
Steven J. Gortler
Half course (spring term). M., W., 2:30–4. EXAM GROUP: 7, 8
Advanced seminar in computer graphics focusing on geometric representations and processing. Topics include: direct manipulation, implicit surfaces, spline presentations, recursively subdivided surfaces, model simplification, surface parameterization and processing, mesh generation and motion capture processing.
Note: Expected to be omitted in 2003–04.
Prerequisite: Computer Science 175 and permission of instructor.

[*Computer Science 278. Rendering and Image Processing in Computer Graphics]
Catalog Number: 4883
Steven J. Gortler
Half course (spring term). Hours to be arranged.
Advanced seminar in computer graphics focusing on image rendering and processing. Topics include: light transport, efficient rendering, image based rendering, texture processing, interactive image processing, image compression and image analysis.

Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 175 and permission of instructor.

[Computer Science 281r. Artificial Intelligence: Reasoning and Planning Systems]
Catalog Number: 0707
Avrom J. Pfeffer
Half course (fall term). M., W., 1–2:30. EXAM GROUP: 6, 7
In-depth introduction to formalisms for knowledge representation and techniques for reasoning and planning. Topics: formal logic-based representations; probabilistic reasoning; nonmonotonic logics; truth-maintenance systems; qualitative reasoning; inheritance hierarchies; computational approaches to reasoning about actions and time, including actions of multiple agents, nonlinear planning, plan recognition; reasoning about knowledge, belief, and action.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 182 or permission of instructor.

Computer Science 282. Probabilistic Reasoning
Catalog Number: 3158
Avrom J. Pfeffer
Half course (fall term). M., W., 1–2:30. EXAM GROUP: 6, 7
In-depth study of principles and techniques for probabilistic reasoning and decision-theoretic planning. Topics include: Bayesian networks and Markov networks; exact and approximate probabilistic inference algorithms; learning Bayesian networks from data; temporal probability models; integrating logic and probability; influence diagrams; Markov decision processes; reinforcement learning.
Prerequisite: Computer Science 181 or permission of instructor.

[Computer Science 283. Computer Vision]
Catalog Number: 4475
Roger W. Brockett
Half course (fall term). M., W., F., at 10. EXAM GROUP: 3
Vision as an ill-posed inverse problem: two-dimensional signal processing; image enhancement and restoration; feature analysis; image segmentation and analysis; structure from motion, texture, and shading; binocular stereo; pattern classification; and applications.
Note: Expected to be given in 2003–04.

[Computer Science 285. Multi-agent Planning Systems]
Catalog Number: 1060
Barbara J. Grosz
Half course (spring term). Tu., Th., 2:30–4. EXAM GROUP: 16, 17
Theories and techniques for multi-agent planning, including formal models of rational agents, collaborative plans, and social systems; computational approaches to distributed planning and problem solving, negotiation, and decision theory for planning; collaborative systems design.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 182 or permission of instructor.

Computer Science 286r. Topics at the Interface between Computer Science and Economics
Catalog Number: 1099 Enrollment: Limited to 20. Preference given to graduate students or upper-class concentrators.
David C. Parkes
Half course (spring term). Tu., Th., 10–11:30. EXAM GROUP: 12, 13
Interplay between computation and incentives within open decentralized computational systems. Mechanisms and market design, negotiation, social-choice, information-economics and privacy. Readings from theoretical CS, AI, operations research, and economics. Spring 2003: Electronic Market Design.
Note: Seminar style.
Prerequisite: Mathematics 21b, Applied Mathematics 21b, or equivalent; Computer Science 121, 124, and 181 or 182, or equivalents; or permission of instructor.

[*Computer Science 287r. Natural Language Processing]
Catalog Number: 3306
Stuart M. Shieber
Half course (spring term). Hours to be arranged.
Principles and techniques of natural language processing, including grammar formalisms, syntactic analysis, semantic interpretation, and associated algorithms.
Note: Expected to be given in 2003–04.
Prerequisite: Computer Science 121 and 152.

Computer Science 288. Computational Models of Discourse
Catalog Number: 1392
Barbara J. Grosz
Half course (spring term). Tu., Th., 2:30–4. EXAM GROUP: 16, 17
Computational theories of discourse (text and dialogue) structure and processing. Topics include: anaphora, focusing, plans and speech acts, plan recognition algorithms, models of collaborative planning, intonation. Discussion of dialogue and text understanding systems. Application to the design of human-computer interface systems.
Prerequisite: Computer Science 182 or 287r or equivalent, or permission of instructor.

Computer Science 299r. Special Topics in Computer Science
Catalog Number: 4592
Venkatesh Narayanamurti
Half course (fall term; repeated spring term). Hours to be arranged.
Supervision of experimental or theoretical research on acceptable computer science problems and supervision of reading on topics not covered by regular courses of instruction.
Note: Open to graduate students and A.B./S.M. candidates only. Students must arrange such work with a member of the Division. This course is graded and is ordinarily taken with the approval of the Committee on Higher Degrees. Applicants should file a project sheet before study cards are filed. Project sheets may be obtained from the Academic Office, Pierce Hall 110.

Graduate Courses of Reading and Research

Reading courses are odd-numbered; research courses are even-numbered.

***Computer Science 305,306. Information Resources: Technology and Policy**
Catalog Number: 6364,3478
Anthony G. Oettinger 2403

***Computer Science 309,310. Computational Mechanism Design, Electronic Marketplaces, and Multi-agent Systems**
Catalog Number: 8764,0931
David C. Parkes 4202

***Computer Science 311,312. Natural Language Processing, AI Planning, and Collaborative Systems**
Catalog Number: 4677,6223
Barbara J. Grosz 1599

***Computer Science 321,322. Databases, Operating System, and Software Design**
Catalog Number: 4085,4086
Margo I. Seltzer 3371

***Computer Science 323,324. Human-Computer Communication through Natural, Graphical, and Artificial Languages**
Catalog Number: 2450,2453
Stuart M. Shieber 2456

***Computer Science 325,326. Programming Languages and Tools**
Catalog Number: 8055,0747
Norman Ramsey 2831

***Computer Science 327,328. Mathematical Logic, Theory of Computation**
Catalog Number: 1160,3576
Harry R. Lewis 4455

***Computer Science 343,344. Computer Architecture: Modeling and Design**
Catalog Number: 3932,9266
David M. Brooks 4222

***Computer Science 345,346. High-Performance Computer Systems**
Catalog Number: 6154,6156
Michael D. Smith 3372

***Computer Science 351,352. Complexity of Computations: Concurrent Programming and Synchronization**
Catalog Number: 0218,0255
Michael O. Rabin 7003

***Computer Science 353,354. Representation and Reasoning, Machine Learning and Decision Making**
Catalog Number: 6816,1843
Avrom J. Pfeffer 2830

***Computer Science 355,356. Computational Complexity, Parallel Computation, Computational Learning, Neural Computation, and Quantum Computation**
Catalog Number: 0345,0346
Leslie G. Valiant 7396

***Computer Science 357,358. Computational Complexity, Cryptography, and Pseudorandomness**
Catalog Number: 3485,8641
Salil P. Vadhan 3833

***Computer Science 359,360. Online Algorithms and Randomized Algorithms**
Catalog Number: 2104,1477
Michael D. Mitzenmacher 7748

***Computer Science 375,376. Computer Graphics**
Catalog Number: 6832,7313
Steven J. Gortler 2824

Courses Related to Ethnic Studies

AN HISTORICAL EDITION OF FAS COURSES OF INSTRUCTION

The following are courses related to themes and issues of ethnicity and race, offered by the Faculty of Arts and Sciences in 2002-2003. Courses appear in 4 categories, the first lists undergraduate core courses, the second lists courses with a primary focus on ethnicity in the United States, the third covers courses related to ethnicity and the United States, and the fourth covers topics on ethnicity outside the United States. Several courses are listed in more than one category. These lists serve as a guide for learning more about diversity in American cultures and other societies. The more complete, descriptive *Ethnic Studies Guidebook* will be available in September. Please consult the Ethnic Studies websitehttp://www.fas.harvard.edu/~cesh/intro.html for more details. *The Faculty Advisory Committee, an interfaculty committee, advises students interested in pursuing Ethnic Studies on their course selection, mentors available, and resources in and around Harvard.*