Continuation of object-centered design and implementation of generic programming.

Lists, tables, stacks, and queues. Templates and generic programming.

Digital representation of objects such as numbers, signals, and 3-dimensional shapes. Algorithms that operate on digital objects. Computer communications, objects, and use of libraries of functions.

Use of computing systems for technical problem solving and to develop the lead to the development of new courses.

Assembly language programming. Data and control. Programming in the C language. Data and control.


Operating Systems
Fall, Spring. 3(3-0) P: (CSE 232 and CSE 260) and (CSE 320 or ECE 331) R: Open only to students in the Department of Computer Science and Engineering or the Computer Engineering major or the LBS Computer Science field of concentration or the LBS Computer Science coordinate major or the Computer Science disciplinary teaching minor. SA: CPS 410

Computer Science and Engineering—CSE

435 Software Engineering
Fall, S(3-0) P CSE 330 and CSE 331 and CSE 335 R: Open only to students in the Department of Computer Science or the Computer Engineering or LBS Computer Science major or the LBS Computer Science coordinate major or the Computer Science disciplinary teaching minor. SA: CSE 475

Software lifecycle including specification, design, coding, testing, and verification of a software product. Stepwise refinement and traceability. Software maintenance and documentation.

440 Introduction to Artificial Intelligence
Fall, S(3-0) P: CSE 331 or CSE 335 R: Open only to students in the Department of Computer Science and Engineering or the Computer Engineering major or the LBS Computer Science field of concentration or the LBS Computer Science coordinate major or the Computer Science disciplinary teaching minor. SA: CSE 440


444 Information Technology Project Management
Spring, S(3-0) Interdepartmental with Information Technology Management and Telecommunication. Administered by Information Technology Management. P: ITM 311 R: Open to students in the Information Technology Specialization.

Practical training and experiences in design, testing, and launch of new information technologies and systems.

450 Translation of Programming Languages
Spring, S(3-0) P: (CSE 331 or CSE 335) and (CSE 320 or ECE 331) R: Open only to students in the Department of Computer Science and Engineering or the Computer Engineering major or LBS Computer Science field of concentration or the LBS Computer Science coordinate major or the Computer Science disciplinary teaching minor. SA: CSE 450


452 Organization of Programming Languages
Fall, S(3-0) P (CSE 331 or CSE 335) and (CSE 320 or ECE 331) R: Open only to students in the Department of Computer Science and Engineering or Computer Engineering major or the LBS Computer Science coordinate major or the LBS Computer Science field of concentration or the Computer Science disciplinary teaching minor. SA: CSE 452


460 Computability and Formal Language Theory
Fall, Spring, S(3-0) P: CSE 331 R: Open only to students in the Department of Computer Science and Engineering or Computer Engineering major or the LBS Computer Science coordinate major or the LBS Computer Science field of concentration or the Computer Science disciplinary teaching minor. SA: CSE 360

Formal models of computation such as finite state automata, pushdown automata and Turing machines. Formal definitions of languages, problems, and language classes including recursive, recursive-like enumerable, regular, and context free languages. The relationships among various models of computation, language classes, and problems. Church's thesis and the limits of computability. Proofs of program properties including correctness.

471 Media Processing and Multimedia Computing
Fall, S(3-0) P: CSE 320 or CSE 331 or CSE 335 R: Open only to students in the Department of Computer Science and Engineering or in the Computer Engineering major or in the Lyman Briggs Computer Science Coordinate Major or in the Lyman Briggs Computer Science field of concentration or in the Computer Science Discipline Teaching Minor.


472 Computer Graphics
Spring, S(3-0) P: (MTH 234 or LB 220) and (CSE 331 or CSE 335) R: Open to juniors or seniors or graduate students in the Department of Computer Science and Engineering and open to juniors or seniors in the Computer Engineering major or in the Lyman Briggs Computer Science Coordinate Major or in the Lyman Briggs Computer Science field of concentration or in the Computer Science Discipline Teaching Minor.


473 Fundamentals of 3D Game Development
Fall, S(3-0) P: MTH 234 and (CSE 320 or CSE 331 or CSE 335) R: Open to juniors or seniors or graduate students in the Department of Computer Science and Engineering or in the Computer Engineering major or in the Lyman Briggs Computer Science Coordinate Major or in the Lyman Briggs Computer Science field of concentration or in the Computer Science Discipline Teaching Minor.

Fundamental algorithms and techniques for 3D computer game development including geometric transformations, procedural and keyframe animation, models and scene graphs, skeletal animation and skinned characters, illuminations and shading, collision detection, and level of detail.

475 Introduction to Computational Linguistics
Fall, S(3-0) Interdepartmental with Linguistics. Administered by Linguistics. P: CSE 232 and LIN 401

Computer science of linguistic theories and their application in natural language processing systems. Stochastic and categorical automata for morphological analysis. Rule systems for grammars. Parsing algorithms for syntactic and semantic analysis, with implications for cognitive models of human sentence processing. Probabilistic models of linguistic events.

480 Database Systems
Spring, S(3-0) P: CSE 331 and (CSE 320 or ECE 331) R: Open only to students in the Department of Computer Science and Engineering or the Computer Engineering major or the LBS Computer Science field of concentration or the LBS Computer Science coordinate major or the Computer Science disciplinary teaching minor. SA: CPS 480

Storage and access to physical databases including indexing, hashing, and range accesses. Relational data models, database design principles, query languages, query optimization, transaction processing and recovery techniques. Object-oriented and distributed databases.

484 Information Retrieval
Fall, S(3-0) P: CSE 331 RB: STT 351 R: Open only to students in Computer Science or Computer Engineering or Lyman Briggs Computer Science major.


490 Independent Study in Computer Science
Fall, Spring. 1 to 3 credits. A student may earn a maximum of 3 credits in all enrollments for this course. R: Open only to students in the Department of Computer Science or the Computer Engineering major. Approval of department; application required. SA: CPS 490

Supervised individual study in an area of computer science.

491 Selected Topics in Computer Science
Fall, Spring. 1 to 4 credits. A student may earn a maximum of 8 credits in all enrollments for this course. R: Open only to students in the Department of Computer Science or the Computer Engineering major. Approval of department. SA: CPS 491

Topics selected to supplement and enrich existing courses and lead to the development of new courses.

498 Collaborative Design (W)
Fall, Spring, 4(2-4) P: (CSE 335 and CSE 410) and computers or computer science requirement and (CSE 420 or CSE 422 or CSE 435 or CSE 440 or CSE 450 or CSE 452 or CSE 460 or CSE 471 or CSE 472 or CSE 480) R: Open only to students in the Department of Computer Science and Engineering. SA: CSE 449, CSE 478, CSE 479

Development of a comprehensive software and/or hardware solution to a problem in a team setting with emphasis on working with a client. Participation in a design cycle including specification, design, implementation, testing, maintenance, and documentation. Issues of professionalism, ethics, and communication.

802 Pattern Recognition and Analysis
Spring, S(3-0) RB: (CSE 331 and MTH 314 and STT 441) or CSE 331 and MTH 314 and STT 441 R: Open to graduate students in the Department of Computer Science and Engineering or in the Department of Electrical and Computer Engineering.

803 Computer Vision
Fall. 3(3-0) RB: CSE 331 and MTH 314 and STT 351 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 803

812 Advanced Operating Systems
Spring. 3(3-0) RB: CSE 410 and CSE 420 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 812
Parallel and distributed operating systems. Load sharing, scheduling, reliability, recovery, memory management. Distributed file systems, distributed agreement, and object-oriented operating systems.

813 Advanced VLSI Design
Spring. 3(3-0) Interdepartmental with Electrical and Computer Engineering. Administered by Electrical and Computer Engineering. P: ECE 410 SA: EE 813

814 Formal Methods in Software Development
Fall of odd years. 3(3-0) RB: MTH 472 R: Open only to majors in the Department of Computer Science and Engineering or approval of department. SA: CPS 814
Formal specification languages, integrating verification with development. Design and the implementation of term project.

820 Advanced Computer Architecture
Fall, Spring. 3(3-0) Interdepartmental with Electrical and Computer Engineering. Administered by Computer Science and Engineering. RB: CSE 410 and CSE 420 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 820
Instruction set architecture. Pipelining, vector processors, cache memory, high-bandwidth memory design, virtual memory, input and output. Benchmarking techniques. New developments related to single CPU systems.

824 Advanced Computer Networks and Communications
Fall. 3(3-0) RB: CSE 422 R: Open only to graduate students in the Department of Computer Science and Engineering. SA: CPS 824
Advanced topics in emerging computer networking technologies, including high-speed wide area networks and local area networks, wireless and mobile computing networks, optical networks, and multimedia networking.

825 Computer and Network Security
Spring. 3(3-0) RB: CSE 410 and CSE 422
Threat assessments, secure software, intrusions and intrusion detection.

830 Design and Theory of Algorithms
Fall, Spring. 3(3-0) RB: CSE 232 and CSE 460 R: Open only to majors in the Department of Computer Science and Engineering or approval of department. SA: CPS 830
Analysis of algorithms. Algorithm design techniques. Efficient algorithms for classical problems. Intractable problems and techniques to handle them.

835 Algorithmic Graph Theory
Spring. 3(3-0) RB: (CSE 232 and CSE 460) and (MTH 309 or MTH 314) R: Open to students in the Department of Computer Science and Engineering or approval of department. SA: CPS 835
Classical concepts in Graph Theory. Algorithmic aspects of graphs such as finding paths, network flow, spanning trees and matching.

841 Artificial Intelligence
Fall. 3(3-0) RB: CSE 440 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 841
Types of intelligence, knowledge representation, cognitive models. Goal-based systems, heuristic search and games, expert systems. Language understanding, robotics and computer vision, theorem proving and deductive systems, and learning.

842 Natural Language Processing
Spring. 3(3-0) P: CSE 841 R: Programming skills, basic probability and statistics knowledge.
Models and algorithms for natural language processing including pattern, artificial semantics, pragmatics, and discourse. Knowledge-based and statistical approaches to a variety of language related applications.

847 Machine Learning
Spring. 3(3-0) P: CSE 841 R: Algorithm, programming in C or equivalent, probability and statistics, artificial intelligence. R: Open only to students in the Department of Computer Science and Engineering or approval of department.
Computational study of learning and data mining. Strengths and limitations of various learning paradigms, including supervised learning, learning from scalar reward, unsupervised learning, and learning with domain knowledge.

848 Evolutionary Computation
Fall of even years. 3(3-0) Interdepartmental with Electrical and Computer Engineering. Administered by Computer Science and Engineering. RB: CSE 841 and CSE 440 R: Open to graduate students in the Department of Computer Science and Engineering and open to graduate students in the Department of Electrical and Computer Engineering or approval of department.
Investigation of evolutionary computation from a historical, theoretical and application viewpoint. Readings from the present literature, experiments with provided software on the application of evolutionary computation principles.

860 Foundations of Computing
Spring of even years. 3(3-0) RB: CSE 460 R: Open only to majors in the Department of Computer Science and Engineering or approval of department. SA: CPS 860

867 Nature and Practice of Cognitive Science
Spring. 3(3-0) Interdepartmental with Linguistics and Philosophy and Psychology and Zoology. Administered by Zoology. RB: Undergraduate course work in behavioral biology, cognitive psychology, philosophy, linguistics, or artificial intelligence.
Survey of how different disciplines explore the cognitive processes underlying intelligent behavior.

870 Advanced Software Engineering
Spring. 3(3-0) RB: (CSE 470) or undergraduate software engineering course R: Open only to students in the Department of Computer Science and Engineering.
Methods and techniques supporting later lifecycle activities, including software testing and maintenance, reuse, and reverse engineering. Domain-specific software engineering methods. Human-computer interfaces, distributed systems, and visualization techniques.

872 Advanced Computer Graphics
Fall. 3(3-0) RB: CSE 472
Advanced aspects of digital image generation, geometric modeling, computer animation and rendering methods.

875 Advanced Studies in Computational Linguistics
Spring. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. Interdepartmental with Linguistics. Administered by Linguistics. P (LUN 475)
Cutting-edge research in computational linguistics. Expressive formalisms such as tree-adjoining, typological and multi-component string grammars, and their associated parsing and learning problems. Robustness for spoken language understanding. Mathematical theories of language learnability. Logic and probability of finite state techniques.

880 Advanced Database Systems
Fall. 3(3-0) RB: CSE 480 R: Open only to majors in the Department of Computer Science and Engineering or approval of department. SA: CPS 880
Distributed and object-oriented databases and knowledgebase systems. Design theory, query optimization, and transaction processing.

881 Data Mining
Fall. 3(3-0) RB: Programming skills in C, C++, Java and Matlab. Basic knowledge in calculus, probability and statistics.
Techniques and algorithms for knowledge discovery in databases, from data preprocessing and transformation to model validation and post-processing. Core concepts include association analysis, sequential pattern discovery, anomaly detection, predictive modeling, and cluster analysis. Application of data mining to various application domains.

885 Artificial Neural Networks
Spring. 3(3-0) Interdepartmental with Electrical and Computer Engineering. Administered by Electrical and Computer Engineering. SA: EE 885

890 Independent Study
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course. R: Open only to Computer Science or Electrical Engineering majors. Approval of department. SA: CPS 890
Independent study of some topic, system, or language not covered in a regular course.
891 **Selected Topics**  
Fall, Spring. 1 to 3 credits. A student may earn a maximum of 9 credits in all enrollments for this course. R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 891  
Selected topics in computer science of current interest and importance but not covered in a regular course.

899 **Master’s Thesis Research**  
Fall, Spring, Summer. 1 to 8 credits. A student may earn a maximum of 24 credits in all enrollments for this course. R: Open only to Computer Science majors. Approval of department. SA: CPS 899  
Master’s thesis research.

902 **Selected Topics in Recognition by Machine**  
Spring. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. RB: CSE 802 and CSE 803 R: Open only to Computer Science and Electrical Engineering majors. SA: CPS 902  
Advanced topics in pattern recognition and computer vision such as Markov random fields, modeling and recognition of three-dimensional objects, and integration of visual modules.

910 **Selected Topics in Computer Networks and Distributed Systems**  
Spring of even years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. RB: CSE 812 and CSE 812 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 910  
Advanced topics and developments in high-bandwidth computer networks, protocol engineering, and distributed computer systems.

912 **Advanced Topics in Distributed Computing Systems**  
Spring of odd years. 3(3-0) RB: CSE 410 and CSE 812  
Advanced topics and developments in Internet computing, distributed algorithm and operating systems, distributed middleware, high-performance distributed computing, peer-to-peer computing, security and fault tolerance of distributed systems, mobile computing, ubiquitous and pervasive computing, and distributed-data management.

914 **Formal Methods in Software Development**  
Fall. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. P: CSE 814 RB: Undergraduate courses in software engineering and in logic. R: Open to graduate students in the Department of Computer Science and Engineering.  
Current research in selected areas of software engineering such as: approaches for the incorporation of formal methods in software development; current projects using formal methods in software engineering; object-oriented analysis and development techniques; and approaches for the incorporation of user-interface analysis and design in software development.

920 **Selected Topics in High Performance Computer Systems**  
Spring of odd years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. Interdepartmental with Electrical and Computer Engineering, Administered by Computer Science and Engineering. P: CSE 822 R: Open only to students in the Computer Science and Engineering major or approval of department. SA: CPS 920  
Design of high performance computer systems. Seminar format.

921 **Advanced Topics in Digital Circuits and Systems**  
Fall, Spring. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course. Interdepartmental with Electrical and Computer Engineering. Administered by Electrical and Computer Engineering. SA: EE 921  
Topics vary each semester.

941 **Selected Topics in Artificial Intelligence**  
Fall. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. RB: CSE 841 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 941  
Topic such as second generation expert systems, human factors, natural language processing, speech understanding, neural networks, genetic algorithms and opportunistic planning.

960 **Selected Topics in Algorithms and Complexity**  
Spring of odd years. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. RB: CSE 830 and CSE 850 R: Open only to graduate students in the Department of Computer Science and Engineering. Approval of department. SA: CPS 960  
Current research in the general theory of algorithms and computational complexity.

980 **Selected Topics in Database Systems**  
Spring. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course. RB: CSE 880 R: Open only to Computer Science or Electrical Engineering majors. SA: CPS 980  
Recent developments in areas such as distributed and parallel database systems, object oriented database systems, knowledgebase and expert database systems.

999 **Doctoral Dissertation Research**  
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 99 credits in all enrollments for this course. R: Open only to Computer Science majors. Approval of department. SA: CPS 999  
Doctoral dissertation research.