CS 101. COMPUTERS: APPLICATIONS AND IMPLICATIONS. (4 Credits)
The varieties of computer hardware and software. The effects, positive and negative, of computers on human lives. Ethical implications of information technology. Hands-on experience with a variety of computer applications. Lec/lab.

CS 151. INTRODUCTION TO PROGRAMMING I WITH EMBEDDED CONTROL LAB. (4 Credits)
Thorough treatment of the basic elements of C, bitwise operations, flow of control, input/output, functions, arrays, strings, and structures. Lec/lab. CROSSLISTED as ECE 151.
Prerequisites: MTH 111 with C or better or MTH 112 with C or better or MTH 251 with C or better or MTH 251H with C or better

CS 160. COMPUTER SCIENCE ORIENTATION. (3 Credits)
Introduction to the computer science field and profession. Team problem solving. Introduction to writing computer programs. Approaches to teaching course topics vary across sections. Lec/lab.
Equivalent to: CS 160H

CS 160H. COMPUTER SCIENCE ORIENTATION. (3 Credits)
Introduction to the computer science field and profession. Team problem solving. Introduction to writing computer programs. Approaches to teaching course topics vary across sections. Lec/lab.
Attributes: HNRS – Honors Course Designator
Equivalent to: CS 160

CS 161. INTRODUCTION TO COMPUTER SCIENCE I. (4 Credits)
Overview of fundamental concepts of computer science. Introduction to problem solving, software engineering, and object-oriented programming. Includes algorithm design and program development. Lec/lab/rec.
Prerequisites: MTH 112 (may be taken concurrently) with C or better or Math Placement Test with a score of 33 or Math Placement - ALEKS with a score of 061

CS 162. INTRODUCTION TO COMPUTER SCIENCE II. (4 Credits)
Basic data structures. Computer programming techniques and application of software engineering principles. Introduction to analysis of programs. Lec/lab/rec.
Prerequisites: CS 161 with C or better or EECS 161 with C or better

CS 165. ACCELERATED INTRODUCTION TO COMPUTER SCIENCE. (8 Credits)
Overview of the fundamental concepts of computer science. Introduction to problem solving, algorithm development, data types, and basic data structures. Introduction to analysis of algorithms and principles of software engineering. System development and computer programming using procedural/object-oriented paradigms. Offered via Ecampus only.
Prerequisites: MTH 112 with C or better or Math Placement - ALEKS with a score of 075

CS 175. *COMMUNICATIONS SECURITY AND SOCIAL MOVEMENTS. (3 Credits)
Equipping students with the theory and practice of communications security, this course explores how social movements can remain effective in the context of mass surveillance and state repression. Lec/rec. (Bacc Core Course)
Attributes: CPDP – Core, Perspective, Difference/Power/Discrimination

CS 195. WEBSITE DESIGN. (4 Credits)
How to design and publish a static website using an existing publishing platform: Techniques and tools for designing and publishing on the World Wide Web; hypertext and HTMML; site and page design; media integration; issues raised by Internet publishing.
CS 321. INTRODUCTION TO THEORY OF COMPUTATION. (3 Credits)
Survey of models of computation including finite automata, formal grammars, and Turing machines.
Prerequisites: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: CS 321H

CS 321H. INTRODUCTION TO THEORY OF COMPUTATION. (3 Credits)
Survey of models of computation including finite automata, formal grammars, and Turing machines.

CS 325. ANALYSIS OF ALGORITHMS. (4 Credits)
Recurrence relations, combinatorics, recursive algorithms, proofs of correctness.
Prerequisites: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: CS 325H

CS 325H. ANALYSIS OF ALGORITHMS. (4 Credits)
Recurrence relations, combinatorics, recursive algorithms, proofs of correctness.
Attributes: HNRS – Honors Course Designator
Prerequisites: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: CS 325

CS 331. INTRODUCTION TO ARTIFICIAL INTELLIGENCE. (4 Credits)
Fundamental concepts in artificial intelligence using the unifying theme of an intelligent agent. Topics include agent architectures, search, games, logic and reasoning, and Bayesian networks.
Prerequisites: CS 261 with C or better or CS 235H with C or better

CS 340. INTRODUCTION TO DATABASES. (4 Credits)
Design and implementation of relational databases, including data modeling with ER or UML, diagrams, relational schema, SQL queries, relational algebra, user interfaces, and administration.
Prerequisites: CS 290 with C or better

CS 344. OPERATING SYSTEMS I. (4 Credits)
Introduction to operating systems using UNIX as the case study. System calls and utilities, fundamentals of processes and interprocess communication.
Prerequisites: CS 261 with C or better and (CS 271 [C] or ECE 271 [C])
Recommended: Experience programming in the C language

CS 352. INTRODUCTION TO USABILITY ENGINEERING. (4 Credits)
Basic principles of usability engineering methods for the design and evaluation of software systems. Includes the study of human-machine interactions, user interface characteristics and design strategies, software evaluation methods, and related guidelines and standards.
Prerequisites: CS 151 with C or better or CS 161 with C or better or CS 165 with C or better or CS 295 with C or better or ECE 151 with C or better

CS 361. SOFTWARE ENGINEERING I. (4 Credits)
Introduction to the "front end" of the software engineering lifecycle; requirements analysis and specification; design techniques; project management.
Prerequisites: CS 261 with C or better

CS 362. SOFTWARE ENGINEERING II. (4 Credits)
Introduction to the "back end" of the software engineering lifecycle implementation; verification and validation; debugging; maintenance.
Prerequisites: CS 261 with C or better
Recommended: Experience with object-oriented programming and data structures (eg. CS 161, CS 162, CS 361)

CS 370. INTRODUCTION TO SECURITY. (4 Credits)
Introductory course on computer security with the objective to introduce concepts and principles of computer systems security. Notions of security, basic crytographic primitives and their application, basics of authentication and access control, basics of key-management, basics of malware and software security.
Prerequisites: CS 344 (may be taken concurrently) with C or better

CS 372. INTRODUCTION TO COMPUTER NETWORKS. (4 Credits)
Computer network principles, fundamental networking concepts, packet-switching and circuit switching. TCP/IP protocol layers, reliable data transfer, congestion control, flow control, packet forwarding and routing. MAC addressing, multiple access techniques. Lec. CROSSLISTED as ECE 372.
Prerequisites: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
Equivalent to: ECE 372

CS 373. DEFENSE AGAINST THE DARK ARTS. (4 Credits)
Introduction to the current state of the art in anti-malware, computer forensics, and networking, messaging, and web security. Broad introduction to the field of computer security.
Prerequisites: CS 344 with C or better and CS 340 [C] and CS 372 [C]

CS 381. PROGRAMMING LANGUAGE FUNDAMENTALS. (4 Credits)
An introduction to the concepts found in a variety of programming languages. Programming languages as tools for problem solving. A brief introduction to languages from a number of different paradigms.
Prerequisites: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])

CS 391. *SOCIAL AND ETHICAL ISSUES IN COMPUTER SCIENCE. (3 Credits)
In-depth exploration of the social, psychological, political, and ethical issues surrounding the computer industry and the evolving information society. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society
Equivalent to: CS 391H
Recommended: CS 101 or computer literacy

CS 391H. *SOCIAL AND ETHICAL ISSUES IN COMPUTER SCIENCE. (3 Credits)
In-depth exploration of the social, psychological, political, and ethical issues surrounding the computer industry and the evolving information society. (Bacc Core Course)
Attributes: CSST – Core, Synthesis, Science/Technology/Society; HNRS – Honors Course Designator
Equivalent to: CS 391
Recommended: CS 101 or computer literacy

CS 395. WEBSITE MULTIMEDIA. (4 Credits)
How to create and deploy interactive digital multimedia through static websites: Technological, aesthetic, and pedagogical issues of communication using interactive multimedia and hypermedia; techniques for authoring interactive multimedia projects using a variety of digital media roots.
Prerequisites: CS 195 with C or better or ART 120 with C or better and (CS 162 [C] or CS 165 [C])

CS 401. RESEARCH. (1-16 Credits)
Graded P/N.
This course is repeatable for 16 credits.

CS 403. THESIS. (1-16 Credits)
This course is repeatable for 16 credits.

CS 405. READING AND CONFERENCE. (1-16 Credits)
This course is repeatable for 16 credits.
CS 406. PROJECTS. (1-16 Credits)
This course is repeatable for 16 credits.

CS 407. SEMINAR. (1-16 Credits)
Graded P/N.
Equivalent to: CS 407H
This course is repeatable for 16 credits.

CS 407H. SEMINAR. (1-16 Credits)
Graded P/N.
Attributes: HNRS – Honors Course Designator
Equivalent to: CS 407
This course is repeatable for 16 credits.

CS 410. OCCUPATIONAL INTERNSHIP. (1-16 Credits)
This course is repeatable for 16 credits.

CS 419. SELECTED TOPICS IN COMPUTER SCIENCE. (0-5 Credits)
Topics of special and current interest not covered in other courses.
Equivalent to: CS 419H
This course is repeatable for 99 credits.

CS 419H. SELECTED TOPICS IN COMPUTER SCIENCE. (1-5 Credits)
Topics of special and current interest not covered in other courses.
Attributes: HNRS – Honors Course Designator
Equivalent to: CS 419
This course is repeatable for 99 credits.

CS 420. GRAPH THEORY WITH APPLICATIONS TO COMPUTER SCIENCE. (3 Credits)
Directed and undirected graphs; paths, circuits, trees, coloring, planar graphs, partitioning; computer representation of graphs and graph algorithms; applications in software complexity metrics, program testing, and compiling.
Prerequisites: (CS 325 with C or better or CS 325H with C or better)

CS 427. CRYPTOGRAPHY. (4 Credits)
Introduction to the theory and practice of modern cryptography. Fundamental primitives including pseudorandom generators, block ciphers, hash functions. Symmetric-key cryptography for privacy and authenticity. Public-key cryptography based on number-theoretic problems.
Prerequisites: CS 261 with C or better or MTH 355 with C or better

CS 434. MACHINE LEARNING AND DATA MINING. (4 Credits)
Introduction to machine learning and data mining algorithms (supervised learning, unsupervised learning, and reinforcement learning) tools that are widely employed in industrial and research settings.
Prerequisites: CS 325 with C or better or CS 325H with C or better

CS 440. DATABASE MANAGEMENT SYSTEMS. (4 Credits)
Relational database design, normalization, file structures, disk storage, query processing and optimization, team development of database applications.
Prerequisites: CS 261 with C or better and (CS 275 [C] or CS 340 [C])

CS 444. OPERATING SYSTEMS II. (4 Credits)
Principles of computer operating systems: concurrent processes, memory management, job scheduling, multiprocessing, file systems, performance evaluation, and networking. Lec/rec.
Prerequisites: (CS 311 with C or better or CS 344 with C or better) and (CS 271 [C] or ECE 375 [C])

CS 446. NETWORKS IN COMPUTATIONAL BIOLOGY. (3 Credits)
An introduction to biological networks and computational methods for their analysis, inference, and functional modeling. Various network centralities, topological measures, clustering algorithms, and probabilistic annotation models are introduced in the context of protein interaction, gene regulatory, and metabolic networks. The course also surveys bioinformatics methods for data-driven inference of network structure.
Prerequisites: CS 261 with C or better
Recommended: Completion or concurrent enrollment in CS 325

CS 447. WIRELESS EMBEDDED SYSTEMS. (4 Credits)
A hands-on introduction to programming wireless embedded systems (aka the "Internet of Things"). Topics include sensors, actuators, state machines, scheduling, wireless communications, time synchronization, localization, fault tolerance, and security related to cyber-physical systems.
Prerequisites: CS 344 with C or better

CS 450. INTRODUCTION TO COMPUTER GRAPHICS. (4 Credits)
Prerequisites: CS 261 with C or better and (MTH 306 [C] or MTH 306H [C] or MTH 341 [C])

CS 453. SCIENTIFIC VISUALIZATION. (4 Credits)
Applies 3D computer graphics methods to visually understand scientific and engineering data. Methods include hyperbolic projections; mapping scalar values to color spaces; data visualization using range sliders; scalar visualization (point clouds, cutting planes, contour plots, isosurfaces); vector visualization (arrow clouds, particle advection, streamlines); terrain visualization; Delauney triangulation; and volume visualization.
Recommended: Prior experience with Unix or Windows, programming experience.

CS 457. COMPUTER GRAPHICS SHADERS. (4 Credits)
Theoretical and practical treatment of computer graphics shaders, including both RenderMan and GPU shaders. Programming in both RenderMan and OpenGL shading languages.
Recommended: Previous graphics pipeline programming experience.

CS 458. INTRODUCTION TO INFORMATION VISUALIZATION. (4 Credits)
Tools and techniques for designing, developing, and deploying interactive visualizations of abstract data sources. Discusses techniques based on principles from design, cognitive science, and perceptual psychology. Topics include 1D, 2D, 3D, multivariate representations, time-series, graphs and trees, text and documents, and interaction techniques.
Prerequisites: CS 361 with C or better

CS 461. SENIOR SOFTWARE ENGINEERING PROJECT I. (3 Credits)
Utilize software engineering methodology in a team environment to develop a real-world application. Teams will be responsible for all phases of software development, including project planning, requirements analysis, design, coding, testing, configuration management, quality assurance, documentation, and delivery. Three-term sequence required. This course fulfills the WIC requirement for computer science majors.
(Writing Intensive Courses).
Attributes: CWIC – Core, Skills, WIC
Prerequisites: CS 361 with C or better
CS 462. *SENIOR SOFTWARE ENGINEERING PROJECT II. (3 Credits)
Utilize software engineering methodology in a team environment to
develop a real-world application. Teams will be responsible for all phases
of software development, including project planning, requirements
analysis, design, coding, testing, configuration management, quality
assurance, documentation, and delivery. Three-term sequence required.
(Writing Intensive Courses)
Attributes: CWIC – Core, Skills, WIC
Prerequisites: CS 362 with C or better and CS 461 [C]

CS 463. SENIOR SOFTWARE ENGINEERING PROJECT. (2 Credits)
Utilize software engineering methodology in a team environment to
develop a real-world application. Teams will be responsible for all phases
of software development, including project planning, requirements
analysis, design, coding, testing, configuration management, quality
assurance, documentation, and delivery. Three-term sequence required.
Prerequisites: CS 462 with C or better

CS 464. OPEN SOURCE SOFTWARE. (4 Credits)
Provides a theoretical foundation of the history, key concepts,
technologies, and practices associated with modern Free and Open
Source Software (FOSS) projects, and gives students an opportunity to
explore and make contributions to FOSS projects with some mentoring
and guidance.
Prerequisites: CS 261 with C or better or CS 361 with C or better

CS 466. WEB-BASED START-UP PROJECT. (4 Credits)
Real-world, hands-on learning in a high-tech web/mobile-based company
environment. Research in the development of product ideas, hypotheses,
and business models to create customer experiments. Prototyping and
statistical analysis to develop, optimize, and evaluate solutions. Rapid
iteration/refactoring based on customer input, web analytics, and user
engagement metrics. Offered at OSU-Cascades only.
Corequisites: CS 461

CS 467. ONLINE CAPSTONE PROJECT. (4 Credits)
Real-world team-based experience with the software engineering
design and delivery cycle, including requirements analysis and
specification, design techniques, and requirements and final project
written documentation. For students in the online CS double-degree
program only.
Prerequisites: CS 344 with C or better and CS 361 [C] and CS 362 [C]

CS 468. INCLUSIVE DESIGN (HCI). (4 Credits)
Inclusive design is designing software that works for a wide variety
of differently abled customers. Teaches the skills needed to design
inclusively without having to have a separate design for each differently
abled customer.
Prerequisites: CS 352 with C or better
Recommended: CS 565 with a minimum grade of C

CS 472. COMPUTER ARCHITECTURE. (4 Credits)
Computer architecture using processors, memories, and I/O devices
as building blocks. Issues involved in the design of instruction set
architecture, processor, pipelineing and memory organization. Design
philosophies and trade-offs involved in Reduced Instruction Set
Computer (RISC) architectures. Lec/lab. CROSSLISTED as ECE 472/
ECE 572.
Prerequisites: ECE 375 with C or better
Equivalent to: ECE 472

CS 475. INTRODUCTION TO PARALLEL PROGRAMMING. (4 Credits)
Theoretical and practical survey of parallel programming, including a
discussion of parallel architectures, parallel programming paradigms, and
parallel algorithms. Programming one or more parallel computers in a
higher-level parallel language.
Prerequisites: CS 325 with C or better or CS 325H with C or better

CS 476. ADVANCED COMPUTER NETWORKING. (4 Credits)
Advanced networking concepts: source/channel coding, queuing theory,
router design, network architectures (Intserv, DiffServ, MPLS), multimedia
protocols (TFRC, RTP), overlay networks, and wireless standards
(Bluetooth 802.11b, 3/4G). CROSSLISTED as ECE 476/ECE 576.
Prerequisites: (CS 372 with C or better or ECE 372 with C or better) and
(ECE 353 [C] or ST 314 [C] or ST 314H [C])

CS 477. INTRODUCTION TO DIGITAL FORENSICS. (4 Credits)
Introduces concepts related to digital forensics, its role and importance,
and tools and techniques for collecting and curating digital evidence.
The course will also discuss the role of evidence in the justice system
and some legal aspects as they pertain to digital forensics. It will introduce
tools and techniques for computer and network forensics.
Prerequisites: CS 344 with C or better and CS 370 [C]

CS 478. NETWORK SECURITY. (4 Credits)
Basic concepts and techniques in network security risks and
vulnerabilities, applied cryptography and various network security
protocols. Coverage of high-level concepts such as authentication,
confidentiality, integrity, and availability applied to networking systems.
Fundamental techniques including authentication protocols, group
key establishment and management, trusted intermediaries, public
key infrastructures, SSL/TLS, IPSec, firewalls and intrusion detection
CROSSLISTED as ECE 478.
Prerequisites: CS 372 with C or better or ECE 372 with C or better
Equivalent to: ECE 478
Recommended: CS 370

CS 480. TRANSLATORS. (4 Credits)
An introduction to compilers; attribute grammars, syntax-directed
translation, lex, yacc, LR(1) parsers, symbol tables, semantic analysis,
and peep-hole optimization.
Prerequisites: (CS 344 with C or better or CS 311 with C or better) and
CS 321 [C]

CS 491. COMPUTER SCIENCE SKILLS FOR SIMULATION AND GAME
PROGRAMMING. (4 Credits)
Game and simulation development is very much a data and math-
intensive activity. A certain number of actions must be produced, and
producing them by hand is hard. This is a middleware CS course that fills
in many of the missing pieces for those wanting to enter the simulation
and game development worlds in a software tool-building capacity.
Prerequisites: CS 261 with C or better and (CS 225 [C] or MTH 231 [C])
and MTH 252 [C]

CS 492. MOBILE SOFTWARE DEVELOPMENT. (4 Credits)
Introduction to concepts and techniques for developing mobile
applications. Students will become familiar with modern mobile structure,
implementation, development tools, and workflow.
Prerequisites: CS 344 with C or better

CS 493. CLOUD APPLICATION DEVELOPMENT. (4 Credits)
Covers developing RESTful cloud services, an approach based on
representational state transfer technology, an architectural style
and approach to communications used in modern cloud services
development.
Prerequisites: CS 290 with C or better and CS 340 [C] and CS 372 [C]
CS 495. INTERACTIVE MULTIMEDIA PROJECTS. (4 Credits)
Students apply principles and procedures of digital art, design, communication, and software authoring while working on large integrated media projects.
Recommended: CS 395

CS 496. MOBILE AND CLOUD SOFTWARE DEVELOPMENT. (4 Credits)
Introduction to the concepts and techniques for developing mobile and cloud applications.
Prerequisites: CS 344 with C or better or CS 311 with C or better
Recommended: Working knowledge of at least one operating system

CS 499. SPECIAL TOPICS. (1-16 Credits)
This course is repeatable for 16 credits.

CS 501. RESEARCH. (1-16 Credits)
Graded P/N.
This course is repeatable for 99 credits.

CS 503. COMPUTER SCIENCE MS THESIS. (1-16 Credits)
This course is repeatable for 999 credits.

CS 505. READING AND CONFERENCE. (1-16 Credits)
This course is repeatable for 20 credits.

CS 506. PROJECTS. (1-16 Credits)
Graded P/N.
This course is repeatable for 99 credits.

CS 507. SEMINAR. (1-16 Credits)
Graded P/N.
This course is repeatable for 16 credits.

CS 511. PROGRAMMING AND DATA STRUCTURES. (4 Credits)
Computer programming, problem solving, data structures, object-oriented programming, recursion, sorting, dynamic programming, asymptotic time complexity.
Recommended: College algebra, plus the ability to navigate an operating system, manipulate files, and use a command line.

CS 512. DATA SCIENCE TOOLS AND PROGRAMMING. (4 Credits)
Accessing and distributing data in the cloud; relational and non-relational databases; map reduction; cloud data processing; load balancing; types of data-stores used in the cloud.
Recommended: CS 511 or an equivalent course or programming experience in in a high-level language like Python, Java or C++.

CS 515. ALGORITHMS AND DATA STRUCTURES. (4 Credits)
Greedy algorithms, divide and conquer, dynamic programming, network flow, data structures.
Recommended: Undergraduate course in algorithms

CS 516. THEORY OF COMPUTATION AND FORMAL LANGUAGES. (4 Credits)

CS 517. THEORY OF COMPUTATION. (4 Credits)
Turing machines, decidability, NP-completeness, complexity classes, randomized computation, relativization, circuit complexity, interactive proof systems, lower bounds, cryptography.

CS 519. SELECTED TOPICS IN COMPUTER SCIENCE. (0-5 Credits)
Topics of special and current interest not covered in other courses. May not be offered every year.
This course is repeatable for 99 credits.

CS 520. GRAPH THEORY WITH APPLICATIONS TO COMPUTER SCIENCE. (3 Credits)
Directed and undirected graphs; paths, circuits, trees, coloring, planar graphs, partitioning; computer representation of graphs and graph algorithms; applications in software complexity metrics, program testing, and compiling.
Recommended: CS 325 and MTH 232

CS 521. COMPUTABILITY. (4 Credits)
Recommended: CS 516

CS 523. ADVANCED ALGORITHMS. (4 Credits)
Approximation algorithms, randomized and probabilistic algorithms, online algorithms.
Recommended: CS 515

CS 524. NP-COMPLETE AND HARDER PROBLEMS. (4 Credits)
Recommended: CS 523

CS 527. ERROR-CORRECTING CODES. (4 Credits)
Hamming codes, linear codes, cyclic codes, BCH and Reed-Solomon codes. Introduction to Galois fields. Encoding and decoding algorithms. Burst error correcting codes, asymmetric and unidirectional codes. Applications of codes for computer systems.
Recommended: Discrete math and probability

CS 529. SELECTED TOPICS IN THEORETICAL COMPUTER SCIENCE. (1-5 Credits)
Topics of interest in algorithms and theory of computation. Topics include approximation algorithms, planar graph algorithms, distributed algorithms, combinatorial optimization, computational geometry.
This course is repeatable for 99 credits.

CS 531. ARTIFICIAL INTELLIGENCE. (4 Credits)

CS 532. ADVANCED ARTIFICIAL INTELLIGENCE. (4 Credits)
Recommended: CS 531

CS 533. INTELLIGENT AGENTS AND DECISION MAKING. (4 Credits)
Recommended: CS 531
CS 534. MACHINE LEARNING. (4 Credits)

CS 535. DEEP LEARNING. (4 Credits)
Prerequisites: CS 534 with B or better

CS 536. PROBABILISTIC GRAPHICAL MODELS. (4 Credits)
Representation of probabilistic graphical models, both directed (Bayesian networks) and undirected (Markov networks). Exact and approximate inference techniques. Parameter and structure learning from data.
Recommended: Strong programming skills

CS 537. COMPUTER VISION I. (3 Credits)
An introduction to low-level computer vision and visual geometry. Topics of interest include the following: detection of interest points and edges, matching points and edges, color models, projective geometry, camera calibration, epipolar geometry, homography, image stitching, and multiframe tracking.
Recommended: Undergraduate-level statistics, probability, calculus, linear algebra, good programming skills, machine learning or AI

CS 539. SELECTED TOPICS IN ARTIFICIAL INTELLIGENCE. (1-5 Credits)
Advanced topics in artificial intelligence. Typical topics include machine learning for sequential and spatial data, knowledge representation and inference, probabilistic modeling of complex systems, data mining and information extraction.
This course is repeatable for 12 credits.

CS 540. DATABASE MANAGEMENT SYSTEMS. (4 Credits)
Purpose of database systems, levels of data representation. Entity-relationship model. Relational systems: data definition, data manipulation, query language (SQL), relational calculus and algebra, data dependencies and normal forms. DBTG network model. Query optimization, recovery, concurrency control.
Recommended: CS 261

CS 544. OPERATING SYSTEMS II. (4 Credits)
Principles of computer operating systems: concurrent processes, memory management, job scheduling, multiprocessing, file systems, performance evaluation, and networking. Lec/rec.
Recommended: (CS 311 or CS 344) and (CS 271 or ECE 375)

CS 546. NETWORKS IN COMPUTATIONAL BIOLOGY. (3 Credits)
An introduction to biological networks and computational methods for their analysis, inference, and functional modeling. Various network centralities, topological measures, clustering algorithms, and probabilistic annotation models are introduced in the context of protein interaction, gene regulatory, and metabolic networks. The course also surveys bioinformatics methods for data-driven inference of network structure.
Recommended: Completion or concurrent enrollment in CS 325

CS 549. SELECTED TOPICS IN INFORMATION-BASED SYSTEMS. (1-5 Credits)
Current topics in information-based systems, e.g. information management for CAD, geographical information systems, distributed information systems, data models for complex applications. This course is repeatable for 99 credits.
Recommended: CS 540

CS 550. INTRODUCTION TO COMPUTER GRAPHICS. (4 Credits)
Recommended: CS 261 and (MTH 306 or MTH 306H or MTH 341)

CS 551. COMPUTER GRAPHICS. (4 Credits)
3-D graphics hardware: Line and polygon scan conversion, modeling transformations, viewing transformations, matrix stacks, hierarchical models, perspective and orthographic projections, visible surface determination, illumination models, shading models, texture mapping, ray tracing.
Recommended: CS 450 or CS 550

CS 552. COMPUTER ANIMATION. (4 Credits)
Traditional animation concepts: production pipeline, keyframing implementation, interpolation, point-mass dynamics, spring-mass systems, rigid body dynamics, forward and inverse kinematics, human motion control, motion capture.
Recommended: CS 551

CS 553. SCIENTIFIC VISUALIZATION. (4 Credits)
Applies 3D computer graphics methods to visually understand scientific and engineering data. Methods include hyperbolic projections; mapping scalar values to color spaces; data visualization using range sliders; scalar visualization (point clouds, cutting planes, contour plots, isosurfaces); vector visualization (arrow clouds, particle advection, streamlines); terrain visualization; Delauney triangulation; and volume visualization.
Recommended: Prior experience with Unix or Windows, programming experience.

CS 554. GEOMETRIC MODELING IN COMPUTER GRAPHICS. (4 Credits)
Advanced topics in computer graphics focusing on representation and processing of polygonal models and their application. Surface fundamentals; discrete differential geometry and topology; data structures for representing 3-D surfaces; surface subdivision and smoothing; mesh simplification and multi-resolution representation of 3-D surfaces; geometry compression; surface parameterization; geometry remeshing; topological simplification; implicit surfaces.
Recommended: CS 450

CS 555. SIGNAL AND IMAGE PROCESSING. (4 Credits)
Fundamental aspects of signal and image processing including image acquisition and display, histograms, level-set and geometric operations, convolutions, Fourier transform, image filtering, sampling theory, image transforms, human vision, color, morphological operations, and image compression.
Recommended: Knowledge of C/C++
CS 556. COMPUTER VISION. (4 Credits)
Algorithm development for automatic interpretation of the three-dimensional world that is captured in a set of images; cameras and image formation; color; keypoint and edge detection; perceptual grouping; segmentation; shape representation; texture; object recognition; optical flow; motion estimation and tracking; and 3-D scene reconstruction from motion and stereo.
Recommended: Basic statistics, probability, calculus, linear algebra, good programming skills, machine learning or AI

CS 557. COMPUTER GRAPHICS SHADERS. (4 Credits)
Theoretical and practical treatment of computer graphics shaders, including both RenderMan and GPU shaders. Programming in both RenderMan and OpenGL shading languages.
Recommended: Previous graphics pipeline programming experience.

CS 559. SELECTED TOPICS IN COMPUTER GRAPHICS AND VISION. (1-5 Credits)
Advanced topics in graphics, animation, and vision. Topics include distribution ray tracing, global-illumination, radiosity, image-based modeling and rendering, vision-assisted image and video editing, 3-D vision, 3-D virtual environments, 3-D interaction, control for physical simulation, motion graphs, computational geometry, etc.
This course is repeatable for 12 credits.

CS 560. DATA-DRIVEN SOFTWARE ENGINEERING. (4 Credits)
An overview of data-driven empirical research methods that can be used to understand the different aspects of software engineering.
Prerequisites: CS 561 with C or better

CS 561. SOFTWARE ENGINEERING METHODS. (4 Credits)
Master software engineering methods and supporting tools in the context of agile processes. Teams will engage in all aspects of software development including design, testing, implementation, deployment and maintenance. 3 hours of lecture per week plus one-hour independent lab per week.
Recommended: CS 362

CS 562. SOFTWARE PROJECT MANAGEMENT. (4 Credits)
Master software project management with an emphasis on timely, cost-effective delivery of high-quality systems. Learn about existing techniques and supporting tools, with a particular focus on coordination and project management. 3 hours of lecture per week plus one-hour independent lab per week.
Recommended: CS 561

CS 563. SOFTWARE MAINTENANCE AND EVOLUTION. (4 Credits)
Contribute to the cutting-edge of software engineering. Learn about existing techniques and supporting tools, with a particular focus on maintenance and evolution. Identify opportunities to support software maintenance and evolution more effectively, by creating new knowledge and supporting systems through research and innovation. 3 hours of lecture per week plus one-hour independent lab per week.
Prerequisites: CS 561 with C or better

CS 564. FIELD STUDIES IN SE AND HCI. (4 Credits)
Deals with the type of empirical study known as the "case" study. These are studies that collect data from natural software development situations as they really occur in the field, in which the researcher does not manipulate or "control" anything. The course is an end-to-end coverage of the process. Mainly focuses on case studies involving human software developers in the field. The student will conduct a field study as part of this course.

CS 565. HUMAN-COMPUTER INTERACTION. (4 Credits)
Basic principles of Human-Computer Interaction (HCI) for the design and evaluation of software systems. Includes research methods for studying human-machine interactions and user interfaces, design strategies, software evaluation methods, and related guidelines and standards.

CS 567. LABORATORY STUDIES IN SE AND HCI. (4 Credits)
Empirical lab studies of software development. Covers how to go about designing, preparing for, running, analyzing, and writing-for-publication lab experiments of programming situations involving human subjects. This is an end-to-end coverage of the entire process, and will put students in a position to conduct lab studies of their own with human subjects.

CS 568. INCLUSIVE DESIGN (HCL). (4 Credits)
Inclusive design is designing software that works for a wide variety of differently abled customers. Teaches the skills needed to design inclusively without having to have a separate design for each differently abled customer.
Recommended: CS 352 [C] or CS 565 [C]

CS 569. SELECTED TOPICS IN SOFTWARE ENGINEERING. (1-5 Credits)
Topics include new programming methodologies, productivity, software development, software complexity metrics.
This course is repeatable for 99 credits.
Recommended: CS 561

CS 570. HIGH PERFORMANCE COMPUTER ARCHITECTURE. (4 Credits)
Advanced concepts in computer architecture. Performance improvement employing advanced pipelining and multiple instruction scheduling techniques. Issues in memory hierarchy and management. CROSSLISTED as ECE 570.
Equivalent to: ECE 472 or ECE 572

CS 572. COMPUTER ARCHITECTURE. (4 Credits)
Computer architecture using processors, memories, and I/O devices as building blocks. Issues involved in the design of instruction set architecture, processor, pipelining and memory organization. Design philosophies and trade-offs involved in Reduced Instruction Set Computer (RISC) architectures. Lec/lab. CROSSLISTED as ECE 472/ ECE 572.
Equivalent to: ECE 472
Recommended: ECE 375

CS 575. INTRODUCTION TO PARALLEL PROGRAMMING. (4 Credits)
Theoretical and practical survey of parallel programming, including a discussion of parallel architecture, parallel programming paradigms, and parallel algorithms. Programming one or more parallel computers in a higher-level parallel language.

CS 576. ADVANCED COMPUTER NETWORKING. (4 Credits)
Equivalent to: ECE 576
Recommended: (CS 372 or ECE 372) and (ECE 353 or ST 314 or ST 314H)
CS 578. CYBER-SECURITY. (4 Credits)
A broad overview of the field of computer and network security.
Essential cryptographic mechanisms such as symmetric and public-key cryptography (e.g., encryption, signatures), network security and authentication protocols (e.g., Kerberos, TLS, IPSec), system security (e.g., access control, firewalls), advanced topics (e.g., searchable encryption, cloud security, secure computation). CROSSLISTED as ECE 578.
Equivalent to: ECE 578

CS 579. TOPICS IN COMPUTER ARCHITECTURE AND PARALLEL PROCESSING. (1-5 Credits)
Current topics in advanced computer architecture and parallel processing.
This course is repeatable for 99 credits.
Recommended: CS 575 or CS 572 or ECE 572

CS 581. PROGRAMMING LANGUAGES I. (4 Credits)
Graduate-level introduction to functional programming and programming language theory. Strongly typed functional programming in Haskell, abstract syntax and grammars, interpreters, denotational semantics, domain theory, and lambda calculus.

CS 582. PROGRAMMING LANGUAGES II. (4 Credits)
Essentials of programming language theory for understanding and conducting programming language research. Dependently typed programming in Agda, Coq, or Idris; operational semantics; type systems; unification and type inference.
Prerequisites: CS 581 with C or better

CS 583. ADVANCED FUNCTIONAL PROGRAMMING. (4 Credits)
Advanced functional programming concepts and strategies, with a focus on techniques useful for the design and implementation of programming languages. Includes higher-order abstract syntax, functors and monads, generalized algebraic data types, functional data structures, and graph reduction.
Prerequisites: CS 581 with C or better

CS 584. HUMAN FACTORS PROGRAMMING LANGUAGES. (4 Credits)
Principles and evaluation methods for designing and evaluating programming languages to emphasize human productivity. Overall goals are (a) to enable students to understand and apply these principles and methods, and (b) to introduce at least four programming languages that aim specifically at supporting human problem solving.

CS 585. DOMAIN-SPECIFIC LANGUAGES. (4 Credits)
Graduate-level introduction to the design and implementation of domain-specific languages (DSLs). Domain analysis; review and revision of language designs; binding constructs to support abstraction; definition of syntax and semantics of DSLs; prototype implementation of embedded DSL.
Prerequisites: CS 581 with C or better

CS 589. SELECTED TOPICS IN PROGRAMMING LANGUAGES. (1-5 Credits)
An in-depth examination of a specific topic of interest in programming language design and implementation. Example topics include object-oriented programming, parallel programming, compiler optimization, programming language semantics.
This course is repeatable for 99 credits.

CS 599. SPECIAL TOPICS. (1-16 Credits)
This course is repeatable for 16 credits.

CS 601. RESEARCH. (1-16 Credits)
Graded P/N.
This course is repeatable for 99 credits.

CS 603. COMPUTER SCIENCE PHD THESIS. (1-16 Credits)
This course is repeatable for 99 credits.

CS 605. READING AND CONFERENCE. (1-16 Credits)
This course is repeatable for 16 credits.

CS 607. SEMINAR. (1-16 Credits)
This course is repeatable for 16 credits.

CS 637. COMPUTER VISION II. (4 Credits)
An introduction to recent advances in visual recognition, including object detection, semantic segmentation, multimodal parsing of images and text, image captioning, face recognition, and human activity recognition. The course covers common formulations of these problems, including energy minimization on graphical models, and supervised machine learning approaches to low- and high-level recognition tasks.
Prerequisites: CS 535 with B+ or better or CS 537 with B- or better
Recommended: CS 519