

COMPUTER SCIENCE (CSCI)

CSCI101. INTRODUCTION TO COMPUTER SCIENCE. 3.0 Semester Hrs.

Introduction to Computer Science is a 3-credit hour ****breadth**** CS course. We cover several topics in this course to help students understand how computers work, e.g., binary numbers, Boolean logic and gates, circuit design, machine language, computer hardware, assembly, operating systems, networking, the Internet protocols, cybersecurity, data science, machine learning, and robotics.

Course Learning Outcomes

- 1. Demonstrate how data is represented in computers
- 2. Define the building blocks and organization of computer hardware
- 3. Describe the differences between machine, assembly, and high-level languages
- 4. Design an efficient algorithm and analyze its time/space complexity
- 5. Implement algorithms that solve problems
- 6. Explain how the Internet works
- 7. Detail how an operating system manages processes
- 8. Evaluate whether one is keeping data private
- 9. Categorize the different threats to computer systems
- 10. Perform the data science process
- 11. Explain the Turing test and how one defines intelligence
- 12. Categorize the different types of machine learning algorithms
- 13. Describe key computer ethics topics
- 14. Recognize the impact of computing on the world
- 15. Design and program Python applications,
- 16. Write loops and decision statements in Python,
- 17. Use lists, tuples, sets, dictionaries, and strings in Python,
- 18. Define the structure/components of a Python program,
- 19. Write functions and pass arguments in Python,
- 20. Write code that reads/writes files in Python,
- 21. Design object-oriented programs with Python classes, and
- 22. Read (trace) basic Python code.

CSCI102. INTRODUCTION TO COMPUTER SCIENCE - LAB. 1.0 Semester Hr.

CSCI 102 is our Introduction to Computer Science LAB course. CSCI 102 is a 1-credit hour programming course in Python that is (A) extremely valuable for those who have never programmed and (B) required for some majors (e.g., MechE). While CSCI 102 is not required for some majors, students with little (or no) prior programming experience are strongly encouraged to enroll.

Course Learning Outcomes

- Design and program Python applications
- Write loops and decision statements in Python
- Use lists, tuples, sets, dictionaries, and strings in Python
- Define the structure/components of a Python program
- Write functions and pass arguments in Python
- Write code that reads/writes files in Python

- Design object-oriented programs with Python classes
- Read (trace) basic Python code

CSCI128. COMPUTER SCIENCE FOR STEM. 3.0 Semester Hrs.

Introduction to programming. Intended for students with no prior experience. Teaches basic programming constructs including data types, conditionals, loops, file I/O, functions, and objects in Python 3. Also covers topics vital to STEM computing, such as data science, best practices for code development, and software ethics. Prerequisite: None
Co-requisite: None.

Course Learning Outcomes

- 1. Analyze a simple empirical problem, break it down into smaller more manageable components, and design algorithmic solutions to these subproblems
- 2. Implement an existing prompt, plan, or design into programmatically correct Python code that produces the expected text, file, or graph output
- 3. Communicate in the language of programming with a computer and other programmers through code reading, writing, and critique
- 4. Critically discuss and reflect on the role technology has in modern society, and the positive and negative impacts their software may have on future users
- 5. Model how basic numeric and non-numeric data is represented in a computer; identify when, why, and how these physical representations diverge from their conceptual equivalents
- 6. Navigate and utilize a computer file system through a GUI, the text console, and code
- 7. Demonstrate effective debugging practices in an IDE to find, characterize, and correct code errors

CSCI195. CS@MINES BRIDGE SEMINAR COURSE. 1.0 Semester Hr.

The purpose of this course is to support Bridge students for success in CS@Mines. Through this course, students will: 1. Engage in activities that show how computing changes the world and impacts daily lives, 2. Delve into a some of the foundational computer science topics (e.g., Binary Numbers, Networking, Operating Systems, Cybersecurity, Cyber Physical Systems, Artificial Intelligence, Machine Learning, Data Science, Bioinformatics, Robotics), and 3. Explore different career paths in the computer science industry. Most importantly, this course will offer students the opportunity to build relationships with their cohort and their program advisors (e.g., Bridge Program Director, Graduate Program Manger), as well as be a source of strength for each other. Prerequisite: Current CS@Mines Bridge Student .

Course Learning Outcomes

- 1. Describe a breadth of foundational computer science topics and how they relate to emphasis areas in computing.
- 2. Implement networking and relationship building techniques within their cohort and other like-minded students.
- 3. Explain the importance of personal development tools and preparedness for careers in computing (e.g., imposter syndrome, the elevator pitch, resume building, navigating career day).
- 4. Summarize the different types of careers that exist in the computer science field.
- 5. Analyze the specific fields in computer science that are of most interest for deeper exploration and potential degree focus area.

CSCI198. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only

once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI200. FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN. 3.0 Semester Hrs.

This course teaches students C++, how to manage memory properly & efficiently at run time, the principles of object-oriented programming, and how to create an algorithm using data structures & abstraction to solve a problem. Recursive data structures & algorithms will be constructed & analyzed when solving problems. Initial principal components of software engineering and design will be introduced and used when drafting a solution to a problem. Programs will be developed using a command line interface. Prerequisite: CSCI101 or CSCI128.

Course Learning Outcomes

- L1. Design an algorithm to solve a problem by breaking the overarching problem into smaller modular components using abstraction and object-oriented design with inheritance.
- L2. Translate the algorithm into a program using proper C++ syntax and fundamental programming constructs (e.g. control structures, I/O, classes).
- L3. Recite & apply frequently used Linux command line commands and compile a program using a command line build system.
- L4. Diagram memory usage, dynamically allocate & deallocate objects at run-time using "The Big Three," and trace the call stack of a program's run-time.
- L5. Define recursion and construct common recursive data structures (e.g. linked list, stack, queue) & algorithms (e.g. search & sort).
- L6. Diagram & construct dynamically allocated data structures (e.g. array, vector, string), recursive data structures, (e.g. linked list, stack, queue), and implement common list operations (e.g. traversal, insertion, removal)
- L7. Define "Big-O" notation, list complexities in increasing order, and analyze an algorithm to compute its run-time performance & memory complexities

CSCI210. SYSTEMS PROGRAMMING. 3.0 Semester Hrs.

The Systems Programming course will teach students how to become proficient with using a Linux operating system from the command line and programming Linux systems. Topics will include: shell scripts; compiling and linking programs; redirecting input and output; controlling jobs from the command line; using advanced SSH functions such as port forwarding and dynamic proxying; file system hierarchy; package management; kernel compilation; network management; C programming with dynamic memory management, function pointers, c-style polymorphism, recursive functions, and data structures; learning how to use a code repository maintenance tool, such as git, from the command line effectively; security, privacy, and encryption concepts; inter-process communication and client-server architectures. Prerequisite: CSCI200.

Course Learning Outcomes

- 1. Identify, select, and apply appropriate Linux commands for file, process, and network management.

- 2. Utilize the command line by designing and creating shell scripts; compiling and linking programs; redirecting input and output of processes; and executing commands for controlling jobs/processes.
- 3. Explain the purpose of and apply advanced SSH functions such as port forwarding, dynamic proxying, effectively.
- 4. Administer a Linux system applying knowledge of the file system hierarchy, package management, kernel compilation, and network management.
- 5. Design and write C programs composed of dynamic memory management, function pointers, c-style polymorphism, recursive functions, and data structures.
- 6. Examine the capabilities of a code repository maintenance tool, such as git, through command line version control.
- 7. Select and implement appropriate security, privacy, and encryption protocols at the operating system level.
- 8. Design and implement programs with client-server architecture using inter-process communication.
- 9. Discuss and apply appropriate time and project management strategies through the development of multiple substantial programming projects throughout the semester.

CSCI220. DATA STRUCTURES AND ALGORITHMS. 3.0 Semester Hrs.

This course teaches students the design and construction of data structures such as hash tables, trees, heaps, and graphs, analysis of operations on data structures, and design and analysis of algorithms on data structures such as graph search and minimum spanning tree algorithms. Applications of data structures and algorithms on them are discussed in the context of computer systems. Students will further refine programming skills in C++ by producing software implementations of selected data structures and algorithms. Prerequisite: CSCI200 with a C- or better, CSCI358 or MATH334.

Course Learning Outcomes

- L1. Perform time and space complexity analyses of algorithms, including sorting and searching algorithms and operations on data structures such as hash tables, trees, graphs, and strings.
- L2. Implement fundamental data structures and algorithms in a high-level programming language.
- L3. Prepare analysis reports detailing theoretical and empirical studies of algorithms and data structures.
- L4. Evaluate and select data structures and algorithms for computing applications such as sorting, indexing, string searching and pattern matching, and path finding.
- L5. Explain and illustrate the function of array-based data structures (dynamic arrays, hash tables, and strings) and algorithms applied to arrays (sorting, searching and pattern matching).
- L6. Explain and illustrate the function of linked data structures (linked lists, trees, and graphs) and algorithms on those data structures.

CSCI250. PYTHON-BASED COMPUTING: BUILDING A SENSOR SYSTEM. 3.0 Semester Hrs.

This course will teach students the skills needed for data collection, analysis, and visualization on a small embedded device (e.g., Raspberry Pi). Students will learn basic Linux, Python, and the programming skills needed to control the hardware and associated sensors. This hands-on course includes a baseline project, four introductory projects (e.g., acoustic, acceleration, magnetic field, optical), and a final Capstone project. The Capstone project will have students create their own application using the techniques learned during the first half of the

semester; students will then present their Capstone project through a formal presentation, write-up, and demonstration. We suggest the student take "Introduction to Computer Science" before this course. Prerequisite: CSCI128. Co-requisite: MATH213, PHGN200.

Course Learning Outcomes

- 1. Create, navigate, and manage files and directory structures using basic Linux shell commands.
- 2. Describe the functionality and purpose of the individual components of the Raspberry Pi Hardware.
- 3. Install the Raspbian operating system onto the Raspberry Pi Hardware and setup basic configuration parameters.
- 4. Download, install, and develop programs using the Spyder Integrated Development Environment (IDE) on the Raspberry Pi Hardware.
- 5. Develop and run basic Python functions and programs in the Linux environment to collect data from sensors using the Raspberry Pi Hardware (e.g., acoustic, acceleration, magnetic field, optical).
- 6. Plot and analyze data from the sensor system and compare to mathematical models.

CSCI260. FORTRAN PROGRAMMING. 2.0 Semester Hrs.

(I) Computer programming in Fortran90/95 with applications to science and engineering. Program design and structure, problem analysis, debugging, program testing. Language skills: arithmetic, input/output, branching and looping, functions, arrays, data types. Introduction to operating systems. Prerequisite: none. 2 hours lecture; 2 semester hours.

CSCI261. PROGRAMMING CONCEPTS. 3.0 Semester Hrs.

This course introduces fundamental computer programming concepts using a high-level language and a modern development environment. Programming skills include sequential, selection, and repetition control structures, functions, input and output, primitive data types, basic data structures including arrays and pointers, objects, and classes. Software engineering skills include problem solving, program design, and debugging practices. Prerequisite: CSCI101.

Course Learning Outcomes

- unchanged

CSCI262. DATA STRUCTURES. 3.0 Semester Hrs.

Defining and using data structures such as linked lists, stacks, queues, binary trees, binary heap, and hash tables. Introduction to algorithm analysis, with emphasis on sorting and search routines. Language skills: abstract data types, templates, and inheritance. 3 hours lecture; 3 semester hours. Prerequisite: CSCI261 with a grade of C- or higher or CSCI200 with a grade of C- or higher.

Course Learning Outcomes

- unchanged

CSCI274. INTRODUCTION TO THE LINUX OPERATING SYSTEM. 1.0 Semester Hr.

Introduction to the Linux Operating System will teach students how to become proficient with using a Linux operating system from the command line. Topics will include: remote login (ssh), file system navigation, file commands, editors, compilation, execution, redirection, output, searching, processes, usage, permissions, compression, parsing, networking, and bash scripting. Prerequisite: CSCI200 or CSCI261.

Course Learning Outcomes

- unchanged

CSCI290. PROGRAMMING CHALLENGES I. 1.0 Semester Hr.

This course is the first of three courses in the Programming Challenges sequence which covers problem solving patterns and paradigms found in technical interviews and programming competitions. The students will learn more advanced data structures and algorithms while focusing on algorithmic complexity to solve problems in a finite amount of time. Co-requisite: CSCI220 or CSCI262.

Course Learning Outcomes

- Solve common programming problems and identify underlying patterns
- Argue and prove correctness of solution
- Determine and argue space and time complexity of solutions
- Combine common algorithms to solve problems
- Improve skills in technical interviews and programming competitions

CSCI295. INDUSTRY EXPLORATION I. 1.0 Semester Hr.

Industry Exploration I provides 1st and 2nd year students an opportunity to explore different career paths in computer science. Each week students meet (over Zoom) with a company that hires a number of computer scientists. Prior to the meeting, students research the company and determine 1-2 specific question(s) to ask during the meeting (i.e., questions specific to the company). During the meeting, students talk with employees at the company to learn more about the types of computer science jobs that exist. After the meeting, students reflect on what was learned during the meeting. At the end of the semester, students have a better understanding of different types of jobs in computer science and what they may want to do in their future careers.

Course Learning Outcomes

- 1. Understand different types of companies that hire CS majors through their research and visits with the companies
- 2. Have answers to questions they have generated, to further their understanding of positions and roles in CS industry
- 3. Improve their professional communication and networking skills through experience
- 4. Shape their future career path by relating what they learn in the course

CSCI298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI303. INTRODUCTION TO DATA SCIENCE. 3.0 Semester Hrs.

This course will teach students the core skills needed for gathering, cleaning, organizing, analyzing, interpreting, and visualizing data. Students will learn basic SQL for working with databases, basic Python programming for data manipulation, and the use and application of statistical and machine learning toolkits for data analysis. The course will be primarily focused on applications, with an emphasis on working with real (non-synthetic) datasets. Prerequisite: CSCI101 or CSCI102 or CSCI128.

Course Learning Outcomes

- 1. Acquire, clean, and organize data from a variety of sources, including raw data files, SQL databases, and online repositories.
- 2. Run simple SQL queries to manipulate and analyze data in relational databases and other data stores implementing SQL front ends.
- 3. Apply toolkits to preprocess large datasets for input to statistical and machine learning algorithms, including methods of feature extraction and dimensionality reduction.
- 4. Apply statistical and machine learning toolkits to large datasets, including applications of regression, classification, and clustering.
- 5. Perform simple visualizations of data.
- 6. Recognize and address the ethical issues arising from data collection and statistical and machine learning.

CSCI306. SOFTWARE ENGINEERING. 3.0 Semester Hrs.

Introduction to software engineering processes and object-oriented design principles. Topics include the Agile development methodology, test-driven development, UML diagrams, use cases and several object-oriented design patterns. Course work emphasizes good programming practices via version control and code reviews. Prerequisite: CSCI210 with grade of C- or higher, CSCI220 with grade of C- or higher or CSCI262 with grade of C- or higher.

Course Learning Outcomes

- unchanged

CSCI340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I, II, S) (WI) Supervised, full-time engineering-related employment for a continuous six-month period (or its equivalent) in which specific educational objectives are achieved. Prerequisite: Second semester sophomore status and a cumulative grade point average of at least 2.00. 0 to 3 semester hours. Cooperative Education credit does not count toward graduation except under special conditions. Repeatable.

CSCI341. COMPUTER ORGANIZATION. 3.0 Semester Hrs.

Covers the basic concepts of computer architecture and organization. Topics include machine level instructions and operating system calls used to write programs in assembly language, computer arithmetics, performance, processor design, and pipelining techniques. This course provides insight into the way computers operate at the machine level. Prerequisite: CSCI200 OR CSCI210 OR (CSCI261 AND CSCI262).

Course Learning Outcomes

- unchanged

CSCI358. DISCRETE MATHEMATICS. 3.0 Semester Hrs.

This course is an introductory course in discrete mathematics and algebraic structures. Topics include: formal logic; proofs, recursion, analysis of algorithms; sets and combinatorics; relations, functions, and matrices; Boolean algebra and computer logic; trees, graphs, finite-state machines, and regular languages. Prerequisite: MATH112 or MATH122.

Course Learning Outcomes

- unchanged

CSCI370. ADVANCED SOFTWARE ENGINEERING. 5.0 Semester Hrs.

This capstone course has three primary goals: (1) to enable students to apply their course work knowledge to a challenging applied problem for a real client, (2) to enhance students' verbal and written communication skills, and (3) to provide an introduction to ethical decision making in computer science. Ethics and communication skills are emphasized in

a classroom setting. The client work is done in small teams, either on campus or at the client site. Faculty advisors provide guidance related to the software engineering process, which is similar to Scrum. By the end of the course students must have a finished product with appropriate documentation. Prerequisite: CSCI306.

Course Learning Outcomes

- unchanged

CSCI390. PROGRAMMING CHALLENGES II. 1.0 Semester Hr.

This course is the second of three courses in the Programming Challenges sequence which covers problem solving patterns and paradigms found in technical interviews and programming competitions. The students will learn more advanced set, counting, & number theory and algorithms while focusing on algorithmic complexity to solve problems in a finite amount of time. Prerequisite: CSCI290. Co-requisite: CSCI358.

Course Learning Outcomes

- Solve common programming problems and identify underlying patterns
- Argue and prove correctness of solution
- Determine and argue space and time complexity of solutions
- Combine common algorithms to solve problems
- Improve skills in technical interviews and programming competitions

CSCI395. INDUSTRY EXPLORATION II. 1.0 Semester Hr.

Industry Exploration II provides 3rd and 4th year students an opportunity to explore different career paths in computer science. Each week students visit a company that hires a number of computer scientists at the company's office. Prior to the visit, students research the company and determine 1-2 specific question(s) to ask during the meeting (i.e., questions specific to the company). During the visit, students are provided a tour of the company's office and the opportunity to talk to employees and learn more about the types of computer science jobs that exist. After the visit, students reflect on what was learned during the visit. At the end of the semester, students have a better understanding of different types of jobs in computer science and what they may want to do in their future careers.

Course Learning Outcomes

- 1. Understand different types of companies that hire CS majors through their research and visits with the companies
- 2. Have answers to questions they have generated, to further their understanding of positions and roles in CS industry
- 3. Improve their professional communication and networking skills through experience
- 4. Discover different company cultures / work environments
- 5. Shape their future career path by relating what they learn in the course

CSCI398. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI399. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must

be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI400. PRINCIPLES OF PROGRAMMING LANGUAGES. 3.0

Semester Hrs.

This course takes a broad view of programming languages, focusing on the fundamental abstractions and principles of language design that transcend the specifics of any particular programming language. The course will emphasize functional programming, develop experience via programming projects, and cover topics such as lambda calculus, higher-order functions, induction, persistence, type systems, syntax, and evaluation. Ultimately, students will have an opportunity to improve programming skills, and develop a deeper understanding of how programming languages are designed and implemented. Prerequisite: CSCI306, CSCI358.

Course Learning Outcomes

- unchanged

CSCI403. DATA BASE MANAGEMENT. 3.0 Semester Hrs.

Design and evaluation of information storage and retrieval systems, including defining and building a database and producing the necessary queries for access to the stored information. Relational database management systems, structured query language, and data storage facilities. Applications of data structures such as lists, inverted lists and trees. System security, maintenance, recovery and definition. Interfacing host languages to database systems and object-relational mapping tools. NoSQL databases and distributed databases. Prerequisite: CSCI200 with a grade of C- or higher or CSCI262 with a grade of C- or higher.

Course Learning Outcomes

- unchanged

CSCI404. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.

General investigation of the Artificial Intelligence field. Several methods used in artificial intelligence such as search strategies, knowledge representation, logic and probabilistic reasoning are developed and applied to practical problems. Fundamental artificial intelligence techniques are presented, including neural networks, genetic algorithms, and fuzzy sets. Selected application areas, such as robotics, natural language processing and games, are discussed. Prerequisite: (CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher) and (MATH201 or MATH334).

Course Learning Outcomes

- n/a

CSCI406. ALGORITHMS. 3.0 Semester Hrs.

Equivalent with MATH406,

Reasoning about algorithm correctness (proofs, counterexamples). Analysis of algorithms: asymptotic and practical complexity. Review of dictionary data structures (including balanced search trees). Priority queues. Advanced sorting algorithms (heapsort, radix sort). Advanced algorithmic concepts illustrated through sorting (randomized algorithms, lower bounds, divide and conquer). Dynamic programming. Backtracking. Algorithms on unweighted graphs (traversals) and weighted graphs (minimum spanning trees, shortest paths, network flows and bipartite matching); NP-completeness and its consequences. Prerequisite: CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher, MATH213 or MATH223, MATH300 or MATH358 or CSCI358.

Course Learning Outcomes

- Reasoning about algorithm correctness (proofs, counterexamples)
- Analysis of algorithms

CSCI410. ELEMENTS OF COMPUTING SYSTEMS. 3.0 Semester Hrs.

This comprehensive course will help students consolidate their understanding of all fundamental computer science concepts. Topics include symbolic communication, Boolean logic, binary systems, logic gates, computer architecture, assembly language, assembler construction, virtual machines, object-oriented programming languages, software engineering, compilers, language design, and operating systems. Using a hardware simulator and a programming language of their choice, students construct an entire modern computer from the ground up, resulting in an intimate understanding of how each component works. Prerequisites: CSCI341 or EENG383. 3 lecture hours, 3 credit hours.

CSCI422. USER INTERFACES. 3.0 Semester Hrs.

User Interface Design is a course for programmers who want to learn how to create more effective software. This objective will be achieved by studying principles and patterns of interaction design, critiquing existing software using criteria presented in the textbooks, and applying criteria to the design and implementation of one larger product. Students will also learn a variety of techniques to guide the software design process, including Cognitive Walkthrough, Talk-aloud and others. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI423. COMPUTER SIMULATION. 3.0 Semester Hrs.

A first course in computer simulation using formal learning groups and emphasizing the rigorous development of simulation applications. Topics will include random number generation, Monte Carlo simulation, discrete event simulation, and the mathematics behind their proper implementation and analysis (random variates, arrival time modeling, infinite horizon statistics, batch means and sampling techniques). The course uses learning group assignments, quizzes, programming projects (using Linux) and exams for assessment. Prerequisite: (CSCI210 or CSCI274) AND CSCI306 AND (MATH201 or MATH334).

Course Learning Outcomes

- All.
- All.
- Simulation software design and implementation.
- Simulation software design and implementation.
- Individual "Student Bounties" in simulation, results of journaled communications.

CSCI425. COMPILER DESIGN. 3.0 Semester Hrs.

An introductory course to the design and construction of compilers. Topics include scanning (lexical analysis), context free grammars, recursive descent (top-down) parsing, LR (bottom up) parsing, syntax directed translation, syntax trees, expression trees, parse trees, intermediate representation, register allocation and target code generation. Students will construct their own tool chain for compiling a simple language, tracking the relevant course topics as they are covered. Prerequisite: CSCI306 AND CSCI341.

Course Learning Outcomes

1. Understand the steps taken by most compilers to translate a program listing to either another language or target code for a machine.
2. Understand and be able to apply the theory of lexical analysis, regular expressions, deterministic finite automata (DFAs), non-

deterministic finite automata (NFAs), and how to use scanner generators (eg flex).

- 3. Know the fundamental principles of context free grammars as well as their associated attributes and properties.
- 4. Understand the constructs for expressing operator precedence and associativity in context free grammars, as well as how language ambiguities are detected and worked around by modern compiler tools.
- 5. Know the theory and implementation of top-down and bottom up parsing, the generation of parse trees, and their translation to abstract syntax trees (ASTs).
- 6. Know program statements are translated to machine language at the CPU op-code and register level.

CSCI432. ROBOT ETHICS. 3.0 Semester Hrs.

This course explores ethical issues arising in robotics and human-robot interaction through philosophical analysis, behavioral and psychological analysis, research ethics education, and the integration of social and ethical concerns in scientific experimentation and algorithm design. Topics include case studies in lethal autonomous weapon systems, autonomous cars, and social robots, as well as higher-level concerns including economics, law, policy, and discrimination. Prerequisite: CSCI200 and MATH201.

Course Learning Outcomes

- 1. Understand the basic ethical theories, concepts, tools, and frameworks for analyzing the social and ethical ramifications of robotics
- 2. Be able to critically examine the ethical significance of the use of robotics in daily and technical fields including human-robot interaction, medicine, relationship, military, etc.
- 3. Develop a critical attitude toward the role of robotics in shaping human society including human perceptions and behaviors
- 4. Be able to use the theories, concepts, tools, and frameworks learned from this class to critically examine emerging robot ethics issues in the society.
- 4. Understand the tradeoffs underlying the design of autonomous moral agents

CSCI436. HUMAN-ROBOT INTERACTION. 3.0 Semester Hrs.

Human-Robot Interaction is an interdisciplinary field at the intersection of Computer Science, Robotics, Psychology, and Human Factors, that seeks to answer a broad set of questions about robots designed to interact with humans (e.g., assistive robots, educational robots, and service robots), such as: (1) How does human interaction with robots differ from interaction with other people? (2) How does the appearance and behavior of a robot change how humans perceive, trust, and interact with that robot? And (3) How can we design and program robots that are natural, trustworthy, and effective? Accordingly, In this course, students will learn (1) how to design interactive robots, (2) the algorithmic foundations of interactive robots; and (3) how to evaluate interactive robots. To achieve these learning objectives, students will read and present key papers from the HRI literature, and complete a final project in which they will design, pilot, and evaluate novel HRI experiments in small groups, with in-class time expected to be split between lecture by the instructor, presentations by students, and either collaborative active learning activities or discussions with researchers in the field. Prerequisite: CSCI200 or CSCI262 and MATH201 or MATH334.

Course Learning Outcomes

- 1. Understand the theoretical foundations and critical application domains of human-robot interaction.
- 2. Employ design techniques to design interactive robots.
- 3. Design human-subject experiments to evaluate interactive robots.
- 4. Perform qualitative and quantitative analysis on the results of human-robot interaction experiments.

CSCI437. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.

Equivalent with CSCI512,EENG507,EENG512, Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. Must be Senior level standing. 3 hours lecture; 3 semester hours. Prerequisite: (MATH201 or MATH334 or EENG311) and MATH332 and (CSCI200 or CSCI261).

Course Learning Outcomes

- 1. Be able to analyze and predict the behavior of image formation, transformation, and recognition algorithms.
- 2. Be able to design, develop, and evaluate algorithms for specific applications.
- 3. Be able to use software tools to implement computer vision algorithms.

CSCI440. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.

Equivalent with MATH440,

This course is designed to introduce the field of parallel computing to all scientists and engineers. The students will be taught how to solve scientific problems using parallel computing technologies. They will be introduced to basic terminologies and concepts of parallel computing, learn how to use MPI to develop parallel programs, and study how to design and analyze parallel algorithms. Prerequisite: CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher, CSCI341.

Course Learning Outcomes

- To follow

CSCI441. COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with MATH441,

This class focuses on the basic 3D rendering and modeling techniques. In particular, it covers the graphics pipeline, elements of global illumination, modeling techniques based on polynomial curves and patches, and shader programming using the GPU. Prerequisite: CSCI220 with a grade of C- or higher or CSCI262 with a grade of C- or higher, MATH332.

Course Learning Outcomes

- Describe, replicate, & modify the graphical pipeline
- Create interactive, real-time graphics applications

CSCI442. OPERATING SYSTEMS. 3.0 Semester Hrs.

Introduces the essential concepts in the design and implementation of operating systems: what they can do, what they contain, and how they are implemented. Despite rapid OS growth and development, the fundamental concepts learned in this course will endure. We will cover the following high-level OS topics, roughly in this order: computer systems, processes, processor scheduling, memory management,

virtual memory, threads, and process/thread synchronization. This course provides insight into the internal structure of operating systems; emphasis is on concepts and techniques that are valid for all computers. Prerequisite: (CSCI 220 with a grade of C- or higher OR CSCI 262 with a grade of C- or higher) AND CSCI341.

Course Learning Outcomes

- n/a

CSCI443. ADVANCED PROGRAMMING CONCEPTS USING JAVA. 3.0 Semester Hrs.

This course will quickly review programming constructs using the syntax and semantics of the Java programming language. It will compare the constructs of Java with other languages and discuss program design and implementation. Object oriented programming concepts will be reviewed and applications, applets, servlets, graphical user interfaces, threading, exception handling, JDBC, and network - ing as implemented in Java will be discussed. The basics of the Java Virtual Machine will be presented. 3 hours lecture, 3 semester hours Prerequisite: CSCI306.

CSCI444. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with MATH444,

This is an advanced computer graphics course, focusing on modern rendering and geometric modeling techniques. Students will learn a variety of mathematical and algorithmic techniques that can be used to develop high-quality computer graphic software. Runtime performance will be evaluated to create optimized real-time graphics applications. In particular, the course will cover global illumination, GPU programming, and virtual and augmented reality. Prerequisites: CSCI441. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Describe, replicate, and modify the modern advanced graphics pipeline
- Create a real-time graphics application using an advanced graphics technique

CSCI445. WEB PROGRAMMING. 3.0 Semester Hrs.

Web Programming is a course for programmers who want to develop web-based applications. It covers basic website design extended by client-side and server-side programming. Students should acquire an understanding of the role and application of web standards to website development. Topics include Cascading Style Sheets (CSS), JavaScript, PHP and database connectivity. At the conclusion of the course students should feel confident that they can design and develop dynamic Web applications on their own. Prerequisite: CSCI306. Co-requisite: CSCI403.

Course Learning Outcomes

- 1. Students will be able to apply software engineering skills to develop an interactive website.
- 2. Students will have an understanding of the dominant web architecture (REST).

CSCI446. WEB APPLICATIONS. 3.0 Semester Hrs.

In Web Applications students will learn how to build effective web-based applications. At the completion of this course, students should know HTTP, Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, Ajax, and RESTful architectures. Additionally students should have considered a variety of issues related to web application architecture, including but not limited to security, performance, web frameworks and cloud-based deployment environments. 3 hours lecture; 3 semester hours. Prerequisite: CSCI220 or CSCI262. Co-requisite: CSCI403.

Course Learning Outcomes

- n/a

CSCI448. MOBILE APPLICATION DEVELOPMENT. 3.0 Semester Hrs.

This course covers basic and advanced topics in mobile application development. Topics include the mobile application lifecycle, user interface components and layouts, storing persistent data, accessing network resources, using location and sensor APIs including GPS and accelerometer, starting and stopping system services, and threading. This is a project-based course where students will design and develop complete applications. Prerequisite: CSCI306 with a grade of C- or higher. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- unchanged

CSCI455. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.

Equivalent with CSCI555,

An introduction to fundamental concepts of game theory with a focus on the applications in networks. Game theory is the study that analyzes the strategic interactions among autonomous decision-makers. Originated from economics. Influenced many areas in Computer Science, including artificial intelligence, e-commerce, theory, and security and privacy. Provides tools and knowledge for modeling and analyzing real-world problems. Prerequisites: CSCI358, CSCI406. 3 hours lecture; 3 semester hours.

CSCI460. SOFTWARE STARTUPS: FROM IDEA TO LAUNCH. 3.0 Semester Hrs.

This course is intended for students who wish to first-hand experience what it takes to get a software idea off the ground. You may already have an idea, or along with classmates, can choose from one of the course?s prefabricated ideas. You will learn how to test your idea with real market feedback ? you will interview potential users, develop user stories, design wireframes (skeletal frameworks that help visualize one?s idea), develop and launch a working beta product, and subsequently iterate on your product with user feedback to continue to refine and drive user adoption. You will learn different go-to-market strategies and gain a deeper understanding of your market. In addition, this course places a real emphasis on interpersonal dynamics and driving to founder-level productivity. Through interactive role-plays, perspective-taking drills, and frameworks for how to give and receive feedback without being hurtful, students will learn how to effectively work together as part of a team. This course is experiential and requires a technical background and strong software development skills to take an idea and implement a hands-on solution over the course of the term. Prerequisite: CSCI306.

Course Learning Outcomes

- In the context of a problem that the student sets out to solve, synthesize the pain of target users through conducting user interviews.
- Create wireframes based on insights from user interactions.
- Develop and launch a working beta product based on user needs.
- Engage in a feedback loop with users to refine their product and drive user adoption.
- Foster high performance in teams by developing proficiency in feedback mechanisms.
- Develop mastery of storytelling in the context of software startup ventures.

CSCI470. INTRODUCTION TO MACHINE LEARNING. 3.0 Semester Hrs.

The goal of machine learning is to build computer systems that improve automatically with experience, which has been successfully applied to a variety of application areas, including, for example, gene discovery, financial forecasting, and credit card fraud detection. This introductory course will study both the theoretical properties of machine learning algorithms and their practical applications. Students will have an opportunity to experiment with machine learning techniques and apply them to a selected problem in the context of term projects. Prerequisite: (CSCI101 or CSCI102 or CSCI128) and (MATH201 or MATH334) and MATH332.

Course Learning Outcomes

- 1. Understand the basic ideas of supervised learning, unsupervised learning and reinforcement learning, as well as their applications to real-world problems.
- 2. Use the linear models for regression and classification and write programs to implement these models using off-the-shelf packages.
- 3. Understand the kernel methods to deal with nonlinear problems and use support vector machines and neural networks to solve real-world problems.
- 4. Understand unsupervised learning and solve clustering and dimensionality reduction problems.
- 5. Understand reinforcement learning and its applications in robotics.

CSCI471. COMPUTER NETWORKS I. 3.0 Semester Hrs.

This introduction to computer networks covers the fundamentals of computer communications, using TCP/IP standardized protocols as the main case study. The application layer and transport layer of communication protocols will be covered in depth. Detailed topics include application layer protocols (HTTP, FTP, SMTP, and DNS), transport layer protocols (reliable data transfer, connection management, and congestion control), network layer protocols, and link layer protocols. In addition, students will program client/server network applications. Prerequisite: (CSCI220 or CSCI262) AND (CSCI210 or CSCI274).

Course Learning Outcomes

- using TCP/IP standardized protocols

CSCI473. ROBOT PROGRAMMING AND PERCEPTION. 3.0 Semester Hrs.

Equivalent with CSCI573,

In this class students will learn the basics of integrated robot system programming and the design and use of algorithms for robot perception. Students will learn how to use the ROS robot middleware for the design of robot systems for perceiving and navigating the world; develop reinforcement learning based models for perception-informed autonomous navigation; and develop computational models for 3D robot perception and perceptual representation of human data. Prerequisite: (CSCI220 or CSCI262),and,(MATH201 or MATH334).

Course Learning Outcomes

- 1. Explain the basic concepts in human-centered robotics
- 2. Model and analyze human behaviors for human-robot interaction applications
- 3. Recognize the cutting-edge human-centered robotics research and applications
- 4. Apply the learned knowledge to other fields

CSCI474. INTRODUCTION TO CRYPTOGRAPHY. 3.0 Semester Hrs.

Equivalent with MATH474,

This course is primarily oriented towards the mathematical aspects of cryptography, but is also closely related to practical and theoretical issues of computer security. The course provides mathematical background required for cryptography, including relevant aspects of number theory and mathematical statistics. The following aspects of cryptography will be covered: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Many practical approaches and most commonly used techniques will be considered and illustrated with real-life examples. Prerequisite: CSCI220 or CSCI262, CSCI358, MATH334 or MATH335 or MATH201.

Course Learning Outcomes

- Unchanged

CSCI475. INFORMATION SECURITY AND PRIVACY. 3.0 Semester Hrs.

Information Security and Privacy provides a hands-on introduction to the principles and best practices in information and computer security. Lecture topics will include basic components of information security including threat assessment and mitigation, policy development, forensics investigation, and the legal and political dimensions of information security. Completion of CSCI274 recommended. Prerequisite: (CSCI220 or CSCI262) and (CSCI 341) and (CSCI 210 or CSCI274).

Course Learning Outcomes

- unchanged

CSCI477. ELEMENTS OF GAMES AND GAME DEVELOPMENT. 3.0 Semester Hrs.

This course provides an overview of computer and video game development along with practical game projects designed to introduce the student to the computer entertainment industry. Topics will include the nature of games, the game player, game play, game design, game mechanics, story and character, game worlds, interface and the game development process. Students will be required to develop code both in C++ and with the use of a game engine. Prerequisite: CSCI220 or CSCI262.

Course Learning Outcomes

- By the end of this course, students will be able to: 1. Define the process of game software design and development from start to finish. 2. Develop a game design document and project plan to be utilized in the development and implementation of a game. 3. Develop a working game product using an existing game engine. 4. Write game programming code and scripting. 5. Identify the core types of AI behavior and their uses, such as pathfinding, fuzzy logic, cooperative behavior, decision trees, neural nets, adaptive and heuristics 6. Discuss the importance of story, character, actions and rewards as part of a successful game design. 7. Implement story, character, gameplay, challenges and mechanics in the design of a game.

CSCI478. INTRODUCTION TO BIOINFORMATICS. 3.0 Semester Hrs.

Bioinformatics is the theory, application and development of computing tools to solve problems and create hypotheses in all areas of biological sciences, which has contributed to advances in biology by providing tools that handle datasets too large and/or complex for manual analysis. This course focuses on an introduction to computational analysis of genetic variation and computational interdisciplinary research in genetics. The topics of this course include introduction to genetics,

identification of genes involved in disease, inferring human population history, technologies for obtaining genetic information, and genetic sequencing, with an emphasis on formulating interdisciplinary problems as computational problems and then solving those problems using computational techniques from statistics and computer science.

Prerequisite: CSCI101 or CSCI102 CSCI128.

Course Learning Outcomes

- 1. knowledge and awareness of the basic principles and concepts of biology, computer science and mathematics;
- 2. existing software to effectively extract information from large databases and to use this information in computer modeling;
- 3. problem-solving skills, including the ability to develop new algorithms and analysis methods;
- 4. an understanding of the intersection of life and information sciences, the core of shared concepts, language and;
- 5. skills the ability to speak the language of structure-function relationships, information theory, gene expression, and database queries.

CSCI480. COMPUTER SCIENCE HONORS THESIS. 3.0 Semester Hrs.

Prerequisite: CSCI306. 3 hours research; 3 semester hours. Repeatable for credit up to 6 semester hours.

Course Learning Outcomes

- TBA

CSCI490. PROGRAMMING CHALLENGES III. 1.0 Semester Hr.

This course is the third of three courses in the Programming Challenges sequence which covers problem solving patterns and paradigms found in technical interviews and programming competitions. The students will learn more advanced dynamic programming, graph theory, and algorithms while focusing on algorithmic complexity to solve problems in a finite amount of time. Prerequisite: CSCI390. Co-requisite: CSCI406.

Course Learning Outcomes

- Solve common programming problems and identify underlying patterns
- Argue and prove correctness of solution
- Determine and argue space and time complexity of solutions
- Combine common algorithms to solve problems
- Improve skills in technical interviews and programming competitions

CSCI498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

CSCI499. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

CSCI500. GRADUATE SEMINAR. 0.0 Semester Hrs.

This zero-credit graduate course builds on the CS department seminars in the colloquium series, which consist of presentations delivered by external or internal invited speakers on topics broadly related to computer science. The seminar is mandatory for all Ph.D. students. The students are required to enroll in the course every semester. Any student who cannot take the course for valid reasons should notify their advisor, who

will then make a request to the CS graduate committee for a waiver. These requests could be for the duration of one semester or longer. The course will be graded as PRG/PRU based on student attendance at the department seminars in the colloquium series - the student has to attend at least two thirds of all the seminars each semester in order to get a PRG grade.

Course Learning Outcomes

CSCI507. INTRODUCTION TO COMPUTER VISION. 3.0 Semester Hrs.

Equivalent with CSCI437,CSCI512,EENG507,EENG512,

(I) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course provides an introduction to this field, covering topics in image formation, feature extraction, location estimation, and object recognition. Design ability and hands-on projects will be emphasized, using popular software tools. The course will be of interest both to those who want to learn more about the subject and to those who just want to use computer imaging techniques. 3 hours lecture; 3 semester hours. Prerequisite: Undergraduate level knowledge of linear algebra, statistics, and a programming language.

Course Learning Outcomes

- 1. Be able to analyze and predict the behavior of image formation, transformation, and recognition algorithms
- 2. Be able to design, develop, and evaluate algorithms for specific applications
- 3. Be able to use software tools to implement computer vision algorithms
- 4. Communicate (in oral and written form) methods and results to a technical audience

CSCI508. ADVANCED TOPICS IN PERCEPTION AND COMPUTER VISION. 3.0 Semester Hrs.

Equivalent with EENG508,

(II) This course covers advanced topics in perception and computer vision, emphasizing research advances in the field. The course focuses on structure and motion estimation, general object detection and recognition, and tracking. Projects will be emphasized, using popular software tools. Prerequisites: EENG507 or CSCI507. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 1. Be able to review the literature on computer vision and create a critical review
- 2. Be able to design, develop, and evaluate algorithms for specific applications
- 3. Be able to use software tools to implement computer vision algorithms
- 4. Communicate (in oral and written form) methods and results to a technical audience

CSCI532. ROBOT ETHICS. 3.0 Semester Hrs.

(II) This course explores ethical issues arising in robotics and human-robot interaction through philosophical analysis, scientific experimentation, and algorithm design. Topics include case studies in lethal autonomous weapon systems, autonomous cars, and social robots, as well as higher-level concerns including economics, law, policy, and discrimination. Graduate enrollees will additionally participate in and report on the results of empirical and computational robot ethics research, with the goal of developing publishable works. Prerequisite: Graduate student standing.

Course Learning Outcomes

- 1 - Understand the basic ethical theories, concepts, tools, and frameworks for analyzing the social and ethical ramifications of robotics
- 2 - Be able to critically examine the ethical significance of the use of robotics in daily and technical fields including human-robot interaction, medicine, relationship, military, etc.
- 3 - Develop a critical attitude toward the role of robotics in shaping human society including human perceptions and behaviors
- 4 - Be able to use the theories, concepts, tools, and frameworks learned from this class to critically examine emerging robot ethics issues in the society.
- 5 - Understand the tradeoffs underlying the design of autonomous moral agents.
- 6 - Conduct robot ethics research grounded in both human-subject experimentation and algorithm development.

CSCI534. ROBOT PLANNING AND MANIPULATION. 3.0 Semester Hrs.

An introduction to planning in the context of robotics covering symbolic and motion planning approaches. Symbolic computation, symbolic domains, and efficient algorithms for symbolic planning; Robot kinematics, configuration spaces, and algorithms for motion planning. Applications of planning will focus on manipulation problems using robot arms.

Course Learning Outcomes

- 1 - Implement algorithms for symbolic computation
- 2 - Construct symbolic planning domains for new scenarios
- 3 - Implement algorithms for symbolic planning via constraint-solving and heuristic search
- 4 - Implement algorithms for sampling-based motion planning
- 5 - Construct kinematic models of robot manipulators
- 6 - Analyze planning algorithms for key properties: correctness, completeness, optimality
- 7 - Evaluate the suitability of different planning approaches and apply appropriate algorithms to new planning scenarios
- 8 - Communicate implementations, analysis, and evaluation in written and oral form

CSCI536. HUMAN-ROBOT INTERACTION. 3.0 Semester Hrs.

Human-Robot Interaction is an interdisciplinary field at the intersection of Computer Science, Robotics, Psychology, and Human Factors, that seeks to answer a broad set of questions about robots designed to interact with humans (e.g., assistive robots, educational robots, and service robots), such as: (1) How does human interaction with robots differ from interaction with other people? (2) How does the appearance and behavior of a robot change how humans perceive, trust, and interact with that robot? And (3) How can we design and program robots that are natural, trustworthy, and effective? Accordingly, In this course, students will learn (1) how to design interactive robots, (2) the algorithmic foundations of interactive robots; and (3) how to evaluate interactive robots. To achieve these learning objectives, students will read and present key papers from the HRI literature, complete an individual final project tailored to their unique interests and skillsets, and complete a group project in which they will design, pilot, and evaluate novel HRI experiments, with in-class time expected to be split between lecture by the instructor, presentations by students, and either collaborative

active learning activities or discussions with researchers in the field. Prerequisite: Data Structures, Probability and Statistics or equivalent.

Course Learning Outcomes

- Understand the theoretical foundations and critical application domains of human-robot interaction.
- Employ design techniques to design interactive robots.
- Design human-subject experiments to evaluate interactive robots.
- Perform qualitative and quantitative analysis on the results of human-robot interaction experiments.

CSCI538. AUGMENTED REALITY. 3.0 Semester Hrs.

Augmented reality is the process of augmenting the real world with virtual content, typically with hand-held or head-mounted displays. This course will provide an overview of augmented reality, including applications, technical foundations (computer vision, optics, graphics, and human factors), and recent developments in the field. Projects will be emphasized, using popular software tools. Augmented reality is a systems-thinking problem where it is helpful to have a good understanding of several areas, including computer vision, optics, graphics, and human-computer interaction. Projects will provide students with opportunities to gain a deeper understanding of these areas, as well as to build a portfolio for possible future careers in augmented reality.

Course Learning Outcomes

- At the completion of the course, you will be able to:

CSCI542. SIMULATION. 3.0 Semester Hrs.

(I) Advanced study of computational and mathematical techniques for modeling, simulating, and analyzing the performance of various systems. Simulation permits the evaluation of performance prior to the implementation of a system; it permits the comparison of various operational alternatives without perturbing the real system. Topics to be covered include simulation techniques, random number generation, Monte Carlo simulations, discrete and continuous stochastic models, and point/interval estimation. Offered every other year. 3 hours lecture; 3 semester hours.

CSCI544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.

Equivalent with MATH544,

This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

CSCI555. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.

Equivalent with CSCI455,

(II) An introduction to fundamental concepts of game theory with a focus on the applications in networks. Game theory is the study that analyzes the strategic interactions among autonomous decision-makers. Originated from economics. Influenced many areas in Computer Science, including artificial intelligence, e-commerce, theory, and security and privacy. Provides tools and knowledge for modeling and analyzing real-world problems. Prerequisites: CSCI406 Algorithms. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 1. Understand the basic concepts in game theory
- 2. Be able to model and analyze real-world problems as games

- 3. Learn about the game theoretic applications in networks
- 4. Have the opportunity to apply game theory to other fields

CSCI560. FUNDAMENTALS OF COMPUTER NETWORKS. 3.0 Semester Hrs.

This fully online course provides an introduction to fundamental concepts in the design and implementation of computer communication networks, their protocols, and applications. Topics include overview of network architectures, applications, network programming interfaces (e.g., sockets), transport, congestion, routing, and data link protocols, addressing, local area networks, wireless networks, and network security. Examples are drawn primarily from the Internet (e.g., TCP, UDP, and IP) protocol suite. If you have taken CSCI 471, you will not receive credit for this course. Prerequisite: CSCI442.

Course Learning Outcomes

- 1) Explain how packet switching works
- 2) Compute and identify potential packet delays in a packet-switched network when provided specific parameters of network conditions.
- 3) Articulate in laymen's terms the following concepts or processes: a) essential principles of a transport layer protocol (reliable data transfer, flow control, congestion control), b) data link layer services and multiple access techniques, c) how mobility is managed in cellular networks, and d) network security issues and provide examples of a few methods that address them
- 4) Apply routing algorithms to find shortest paths for network-layer packet delivery
- 4) Apply routing algorithms to find shortest paths for network-layer packet delivery
- 5) Apply Wireshark, a network sniffing tool, to observe and analyze behaviors of the networking protocols studied in this course
- 6) Design and implement distributed applications using the socket APIs and support for TCP/UDP communications between end hosts

CSCI561. THEORY OF COMPUTATION. 3.0 Semester Hrs.

(I) An introduction to abstract models of computation and computability theory; including finite automata (finite state machines), pushdown automata, and Turing machines. Language models, including formal languages, regular expressions, and grammars. Decidability and undecidability of computational problems. 3 hours lecture; 3 semester hours. Prerequisite: CSCI406.

CSCI562. APPLIED ALGORITHMS AND DATA STRUCTURES. 3.0 Semester Hrs.

(II) Industry competitiveness in certain areas is often based on the use of better algorithms and data structures. The objective of this class is to survey some interesting application areas and to understand the core algorithms and data structures that support these applications. Application areas could change with each offering of the class, but would include some of the following: VLSI design automation, computational biology, mobile computing, computer security, data compression, web search engines, geographical information systems. Prerequisite: MATH/CSCI406. 3 hours lecture; 3 semester hours.

CSCI563. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.

(I) Students are taught how to use parallel computing to solve complex scientific problems. They learn how to develop parallel programs, how to analyze their performance, and how to optimize program performance. The course covers the classification of parallel computers, shared memory versus distributed memory machines, software issues, and hardware issues in parallel computing. Students write programs for state

of the art high performance supercomputers, which are accessed over the network. Prerequisite: Programming experience in C. 3 hours lecture; 3 semester hours.

CSCI564. ADVANCED COMPUTER ARCHITECTURE. 3.0 Semester Hrs.

The objective of this class is to gain a detailed understanding about the options available to a computer architect when designing a computer system along with quantitative justifications for the options. All aspects of modern computer architectures including instruction sets, processor design, memory system design, storage system design, multiprocessors, and software approaches will be discussed. Prerequisite: CSCI341. 3 hours lecture; 3 semester hours.

CSCI565. DISTRIBUTED SYSTEMS. 3.0 Semester Hrs.

This course discusses concepts, techniques, and issues in developing distributed systems in large scale networked environment. Topics include theory and systems level issues in the design and implementation of distributed systems.

CSCI568. DATA MINING. 3.0 Semester Hrs.

This course is an introductory course in data mining. It covers fundamentals of data mining theories and techniques. We will discuss association rule mining and its applications, overview of classification and clustering, data preprocessing, and several application specific data mining tasks. We will also discuss practical data mining using a data mining software. Project assignments include implementation of existing data mining algorithms, data mining with or without data mining software, and study of data mining related research issues. 3 hours lecture; 3 semester hours.

CSCI571. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.

Artificial Intelligence (AI) is the subfield of computer science that studies how to automate tasks for which people currently exhibit superior performance over computers. Historically, AI has studied problems such as machine learning, language understanding, game playing, planning, robotics, and machine vision. AI techniques include those for uncertainty management, automated theorem proving, heuristic search, neural networks, and simulation of expert performance in specialized domains like medical diagnosis. This course provides an overview of the field of Artificial Intelligence. Particular attention will be paid to learning the LISP language for AI programming. Prerequisite: CSCI262.

CSCI572. COMPUTER NETWORKS II. 3.0 Semester Hrs.

This course explores how computer networking is evolving to support new environments, and challenges in building networked systems that are simultaneously highly robust, efficient, flexible, and secure. Detailed topics include wireless and mobile networks, multimedia networking, and network security. In addition, recent research and developments are also studied, which include mobile sensing, Internet of Things (IoT), social computing and networks, mobile ad-hoc networks, wireless sensor networks, software defined networking, and future Internet architecture.

CSCI573. ROBOT PROGRAMMING AND PERCEPTION. 3.0 Semester Hrs.

Equivalent with CSCI473,

In this class students will learn the basics of integrated robot system programming and the design and use of algorithms for robot perception. Students will learn how to use the ROS robot middleware for the design of robot systems for perceiving and navigating the world; develop reinforcement learning based models for perception-informed autonomous navigation; and develop computational models for 3D robot perception and perceptual representation of human data.

Course Learning Outcomes

- 1. Explain the basic concepts in human-centered robotics
- 2. Model and analyze human behaviors for human-robot interaction applications
- 3. Recognize the cutting-edge human-centered robotics research and applications
- 4. Apply the learned knowledge to other fields

CSCI574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.

Equivalent with MATH574,

(I) Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Prerequisite: CSCI262. 3 hours lecture, 3 semester hours.

Course Learning Outcomes

- Explain the basic terms and concepts in cryptography.
- Correlate number theory with cryptography.
- Analyze the limitations of classical cryptographic algorithms.
- Compare the similarities and differences between symmetric and asymmetric encryption algorithms.
- Assess the security strength of cryptographic techniques.
- Choose appropriate cryptographic techniques such as hashing, message authentication, and digital signature for addressing real-world security and privacy problems.
- Critique research work in applied cryptography.

CSCI575. ADVANCED MACHINE LEARNING. 3.0 Semester Hrs.

Machine learning is the study of computer algorithms that improve automatically through experience. Machine learning systems do not have to be programmed by humans to solve a problem; instead, they essentially program themselves based on examples of how they should behave, or based on trial and error experience trying to solve the problem. This course aims at provide students with an understanding of the capabilities of machine learning (especially for deep learning due to its state-of-the-art performance for predicting and understanding data), and the knowledge to formulate the real-world problem to solve it effectively by a combination of computational idea motivations, learning theories, mathematical and optimization backgrounds/tools.

CSCI577. ADVANCED ELEMENTS OF GAMES AND GAME DEVELOPMENT. 3.0 Semester Hrs.

This course provides an overview of computer and video game development along with practical game projects designed to introduce the student to the computer entertainment industry. Topics will include the nature of games, the game player, game play, game design, game mechanics, story and character, game worlds, interface and the game development process. Students will be required to develop code in existing game engines (GameMaker, Unity, and Unreal). Students will also work on a game engine from scratch, using a hybrid software design pattern that is an object-oriented hierarchy with components. The majority of the course will be dedicated to a semester-long game project where

students will create a complete game with a teammate using Agile principles, a backlog, a design document, demos, and a final product with commercial video. Prerequisite: CSCI 306.

Course Learning Outcomes

CSCI578. BIOINFORMATICS. 3.0 Semester Hrs.

Bioinformatics is a blend of multiple areas of study including biology, data science, mathematics and computer science. The field focuses on extracting new information from massive quantities of biological data and requires that scientists know the tools and methods for capturing, processing and analyzing large data sets. Bioinformatics scientists are tasked with performing high-throughput, next-generation sequencing. They analyze DNA sequence alignment to find mutations and anomalies and understand the impact on cellular processes. The bioinformatician uses software to analyze protein structure and its impact on cell function. Learning how to design experiments and perform advanced statistical analysis is essential for anyone interested in this field, which is main goal of this course.

Course Learning Outcomes

- 1. knowledge and awareness of the basic principles and concepts of biology, computer science and mathematics;
- 2. existing software effectively to extract information from large databases and to use this information in computer modeling;
- 3. problem-solving skills, including the ability to develop new algorithms and analysis methods;
- 4. an understanding of the intersection of life and information sciences, the core of shared concepts, language and skills the ability to speak the;
- 5. language of structure-function relationships, information theory, gene expression, and database queries.

CSCI580. ADVANCED HIGH PERFORMANCE COMPUTING. 3.0 Semester Hrs.

This course provides students with knowledge of the fundamental concepts of high performance computing as well as hands-on experience with the core technology in the field. The objective of this class is to understand how to achieve high performance on a wide range of computational platforms. Topics will include sequential computers including memory hierarchies, shared memory computers and multicore, distributed memory computers, graphical processing units (GPUs), cloud and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- These learning outcomes are important for graduate students in computer science, because parallel computers are already pervasive and fully utilizing their power is a critical task for parallel programmers.

CSCI581. QUANTUM PROGRAMMING. 3.0 Semester Hrs.

This course serves as an introduction to programming quantum computers. Students will receive an in depth education in quantum algorithms and their design, and then break into teams to learn the API of a commercially available quantum computing system. They will use this system to write and test simple quantum algorithms, and debug their code to improve its performance against noise and other error sources. Prerequisite: PHGN519.

Course Learning Outcomes

- Building on the education received in Fundamentals of Quantum Information, students will learn:
 1. How to write and implement simple quantum algorithms,
 2. Understand mechanisms by which a quantum speedup can be obtained
 3. Use and execute code on an API of publicly available quantum hardware (e.g. IBM's qiskit, Rigetti's Forest, Google's forthcoming Cirq, and many more)
 4. "Debug" their code to improve its performance given the realities of noise and gate error

CSCI582. COMPUTING BEYOND CPU'S. 3.0 Semester Hrs.

CPUs are no longer fast enough to execute demanding tasks in emerging domains such as artificial intelligence, robotics and mobile computing. Most modern systems come with specialized, i.e., "beyond the CPU", processing units such as GPUs, neural network processors, and other domain-specific accelerators. This class will provide students with knowledge and hands-on experience with accelerators. We will dig deep into the world of specialized computing and: (a) teach students the fundamental computer architecture concepts that lead to the development of accelerators, (b) let the students know about modern accelerators, their internal architectures, and how to program them to solve many prevalent computational problems in an energy and performance efficient way, and (c) provide students a hands-on experience by implementing and running benchmarks on an accelerator of their choice and perform a detailed performance analysis. The course assignments will include weekly paper reading, mini programming assignments, paper presentations (one or two times in the semester) and a semester project that will be carried out on an accelerator of student's choice. The students will be given access to a diverse range of modern heterogeneous processing units that are designed to accelerate mobile, cloud and autonomous workloads. Prerequisite: CSCI 341.

Course Learning Outcomes

CSCI585. INFORMATION SECURITY PRIVACY. 3.0 Semester Hrs.

This course provides an introduction to the principles and best practices in information security and privacy. Lectures will include basic concepts of information security and privacy, fundamental security design principles, major topics in security and privacy, essential knowledge and skills, risk assessment and mitigation, policy development, and so on. In the classroom, students will also present and discuss a list of recent or classic research papers corresponding to the major topics in security and privacy. Outside of the classroom, students will work on homework assignments, security lab exercises, quizzes, research paper summaries, and a course project. Prerequisite: CSCI262 and CSCI341.

Course Learning Outcomes

- 1. Students will deeply understand the fundamental security and privacy protection principles, techniques, and practices.
- 2. Students will properly apply the learned knowledge and skills to analyze and address real-world security and privacy problems.
- 3. Students will properly analyze and evaluate research work in security and privacy protection.
- 4. Students will build up the motivation, capability, or mindset to make innovations in security and privacy protection.

CSCI587. CYBER PHYSICAL SYSTEMS SECURITY. 3.0 Semester Hrs.

(II) This course aims to build a solid foundation for students to identify, analyze, and evaluate real-world security and privacy problems in Cyber Physical Systems, as well as to design and develop secure and usable

solutions for addressing these problems. It focuses on the important security and privacy research topics in representative Cyber Physical Systems such as wireless sensor networks, smart grids, autonomous automotive systems, and robotic systems. It also includes the discussion of the protection of the nation's critical infrastructures such as Food, Health, Water, Energy, Finance, Communication, Manufacturing, Government, and Transportation. The format of the course includes introductory discussions, research paper reading, summaries, and discussions, as well as research projects. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 1. Students will be able to explain the essential security and privacy protection requirements in representative Cyber Physical Systems.
- 2. Students will be able to analyze security and privacy problems in representative Cyber Physical Systems.
- 3. Students will be able to analyze and evaluate research articles in Cyber Physical Systems security and privacy protection.
- 4. Students will be able to design usable solutions for addressing security and privacy problems in representative Cyber Physical Systems.

CSCI598. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI599. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI691. GRADUATE SEMINAR. 1.0 Semester Hr.

Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI698. SPECIAL TOPICS. 6.0 Semester Hrs.

(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI699. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI700. MASTERS PROJECT CREDITS. 1-6 Semester Hr.

(I, II, S) Project credit hours required for completion of the non-thesis Master of Science degree in Computer Science (Project Option). Project under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. Repeatable for credit.

CSCI707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT.

1-15 Semester Hr.

(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT
Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.