Courses

**CMP SCI 1011 Introduction to the Internet and World Wide Web: 3 semester hours**
Intended for any student wishing to utilize the Internet and World Wide Web more effectively. Topics include networking basics, the Internet and World Wide Web, browsers, search engines, Web Services, utilities, tools, online privacy and security. Students will learn to develop a personal web page using skills acquired in the course.

**CMP SCI 1012 Learning to Program Using Virtual Worlds: 3 semester hours**
Introduces modern programming principles without requiring the knowledge of a traditional programming language. Instead, this course utilizes a novel graphical approach that enables the student to create, populate, and manipulate virtual 3-dimensional worlds which resemble video games. The development of these worlds allows students to gain direct experience and skills in using computers to solve problems. Students will create worlds of varying complexity.

**CMP SCI 1250 Introduction to Computing: 3 semester hours**
Prerequisites: MATH 1030 or MATH 1045 with B- or better, or MATH 1100, or MATH 1800, or a 70% on the proctored UMSL ALEKS Math Placement obtained at most one year prior to enrollment in this course. This course provides an introduction to the concepts of computation, problem solving, and computer systems. It covers fundamental programming constructs, basic data types, and modularization using a modern high level language. Problem solving skills are developed through a progression of programming projects.

**CMP SCI 2250 Programming and Data Structures: 3 semester hours**
Prerequisite: CMP SCI 1250. Continuation of CMP SCI 1250. Discusses properties and implementation of abstract data types such as lists, trees, stacks and queues. Introduces procedural and class abstraction, basic program architecture, use of interfaces, modular programming, and file processing.

**CMP SCI 2261 Object-Oriented Programming: 3 semester hours**
Prerequisite: CMP SCI 2250. Introduces object-oriented concepts, terminology, and notation (UML) using Java. Covers encapsulation, classes, objects, inheritance, and the use of class libraries. Additional topics may include graphical user interfaces, applets, and related tools and technologies.

**CMP SCI 2700 Computer Organization and Architecture: 3 semester hours**
Prerequisites: CMP SCI 1250 and CMP SCI 2250 (CMP SCI 2250 can be taken concurrently). This course introduces details of computer systems from architectural and organizational points of view. It covers data representation, basic digital logic circuits, memory types and hierarchies, I/O and storage devices, CPU architectures such as RISC, CISC, parallel, and multi-core.

**CMP SCI 2750 System Programming and Tools: 3 semester hours**
Prerequisites: CMP SCI 2250 and CMP SCI 2700 (CMP SCI 2700 can be taken concurrently). This course covers systems programming, scripting, libraries, utilities, and development tools. Additional programming topics include piping, binary files, exception handling, command-line arguments and symbolic debugging. This course also explores tools available in the Unix/Linux environments.

**CMP SCI 3010 Web Programming: 3 semester hours**
Prerequisites: CMP SCI 2261 (or concurrent enrollment). This course provides a survey of current Web technologies including markup languages (such as HTML/XHTML, CSS, XML), client side languages (such as JavaScript), server side languages (such as PERL, PHP), and Web protocols. Client-server computing projects are a course requirement.

**CMP SCI 3130 Design and Analysis of Algorithms: 3 semester hours**
Prerequisites: CMP SCI 2250, MATH 1320, and MATH 3000. This course addresses the design and analysis of fundamental algorithms in computer science. Studies basic sorting algorithms, priority queues, order statistics, search trees, and hash tables. Analysis techniques may involve time and space complexity analysis of both iterative and recursive algorithms, analysis of algorithm correctness, and amortized complexity analysis. Additional topics may include data compression, string manipulation, greedy algorithms, dynamic programming, and graph traversal.

**CMP SCI 3200 .NET Framework: 3 semester hours**
Prerequisites: CMP SCI 3010. This course introduces the .NET framework and related languages and technologies. Topics will include Visual Studio and C# for OOP and web applications. Additional topics may include ASP.NET with MVC, data access, and windows communication.

**CMP SCI 3410 Video Game Design and Development: 3 semester hours**
Prerequisites: CMP SCI 2261. This course covers major aspects of the design and development of video games, including world/level design, game UI design, game character design, game engine programming, 2D/3D modeling and rendering, game physics and animation. This is a project-based course in which students learn to apply acquired knowledge and skills to building a video game in a team environment.

**CMP SCI 3710 Assembly Language Programming: 3 semester hours**
Prerequisite: CMP SCI 2700. Explores machine architecture concepts and principles through a study of assembly language programming. Topics covered include integer and floating point arithmetic, procedures, conditional processing, strings, macros, and interfaces to high level languages. Programming projects using a commercially available assembly language will be required.

**CMP SCI 3760 Cyber Threats and Defense: 3 semester hours**
Prerequisites: CMP SCI 2250. This course provides students with the basic foundation knowledge in various cyber threats, defense methods and mechanisms. For cyber threats, the course uses an adversary model (resources, capabilities, intent, motivation, access) to cover threats such as password cracking, backdoors, trojans, viruses, wireless attacks, sniffing, spoofing, session hijacking, denial of service, DDoS, BOTs, MAC spoofing, web app attacks, zero-day exploits, and vulnerabilities that enable them. Cyber threat topics include attack timing, social engineering, attack indication, attack trees, insider problem, covert channels, and threat information sources (e.g., CERT). Typical cyber defense mechanisms will also be covered including intrusion detection, honeytrap and honeynets, network monitoring and traffic analysis, access control, DMZ and proxies, network hardening.

**CMP SCI 3780 Software Security: 3 semester hours**
Prerequisites: CMP SCI 2261, CMP SCI 2750, and CMP SCI 3010. This course introduces the basic software security principles and pitfalls, including topics such as buffer, integer and string problems, runtime errors, SQL and command injection. Additional topics may include data protection, secure file access, password and network security.
**CMP SCI 3990 Undergraduate Internship in Computer Science:** 3 semester hours
Prerequisites: Consent of Advisor. The internship provides for a student to attain field experience in an organization related to Computer Science. A student is engaged off-campus for an assignment of at least 320 hours working on a project as directed by his/her supervisor in the host organization. The project should be approved by the student's academic advisor, or a designated faculty member, who will monitor the student's progress. The course cannot be repeated for credit.

**CMP SCI 4010 Advanced Web Development with Java:** 3 semester hours
Prerequisites: CMP SCI 2261 and CMP SCI 3010; or graduate standing. This course covers more advanced Java topics, along with related concepts and technologies for Web development. Topics may include database connectivity, multi threading, security, networking, MVC pattern, testing and source control for Java applications, and server-side topics such as servlets and web servers.

**CMP SCI 4011 Client-Side Technologies:** 3 semester hours
Prerequisites: CMP SCI 3010. This course explores in depth the current state-of-the-art front-end, client-side technologies, focusing on JavaScript. Topics may include MongoDB, AngularJS, React, jQuery, Node.js, Express.js, and CSS.

**CMP SCI 4012 Introduction to Enterprise Web Development:** 3 semester hours
Prerequisites: CMP SCI 4010. This course covers design and implementation issues for enterprise web development, and some popular advanced technologies. Topics include MVC and persistence frameworks, such as Spring and Hibernate. Other topics may include Java Web services, EJB, messaging standards such as JMS, and Java EE design patterns. Students will develop enterprise-level web application projects. Credit cannot be earned for both CMP SCI 4012 and CMP SCI 5012.

**CMP SCI 4020 Introduction to Android Apps: Android Fundamentals:** 3 semester hours
Prerequisites: CMP SCI 4010, or consent of the instructor. This course covers the fundamental programming principles, software architecture and user experience considerations underlying handheld software applications and their development environments. Involves in-depth, hands-on examples, implemented on the Android Platform, and discussion of security. Credit not granted for both CMP SCI 4020 and CMP SCI 5020.

**CMP SCI 4030 Introduction to Intelligent Web:** 3 semester hours
Prerequisites: CMP SCI 3010 and CMP SCI 3130. This course covers the application of artificial intelligence and other modern techniques to help construct, navigate, and experience the Web. Topics may include retrieval models, classification, mining, association, topology, and indexing algorithms such as PageRank and HITS. Credit cannot be earned for both CMP SCI 4030 and CMP SCI 5030.

**CMP SCI 4140 Theory of Computation:** 3 semester hours
Prerequisites: CMP SCI 3130 or graduate standing. This course provides an introduction to the theory of computation. It describes basic computational models, such as finite state machines, pushdown automata, Turing machines and grammars. It also covers the concept of nondeterministic computation and the relationships between different computational models. Additionally it discusses decidability, reducibility, and classification of problems into complexity classes based on their time and space complexity, such as P, NP, and PSPACE.

**CMP SCI 4200 Introduction to Enterprise Web Development:** 3 semester hours
Prerequisites: CMP SCI 2261 and CMP SCI 3010; or graduate standing. This course covers more advanced Java topics, along with related concepts and technologies for Web development. Topics may include database connectivity, multi threading, security, networking, MVC pattern, testing and source control for Java applications, and server-side topics such as servlets and web servers.

**CMP SCI 4202 iOS Apps:** 3 semester hours
Prerequisites: CMP SCI 2261 or consent of the instructor. This course focuses on building more sophisticated iOS apps. May include networking such as web services, Bluetooth and wifi connectivity, graphics and animation in 2-d and 3-d, autolayouts. OpenGL, advanced data sources such as plist and core data, source control and unit testing. May also discuss security topics. Credit not granted for both CMP SCI 4222 and CMP SCI 5222.

**CMP SCI 4250 Programming Languages:** 3 semester hours
Prerequisites: CMP SCI 2261 or graduate standing. This course studies the principles, approaches, and trade-offs in modern programming languages, including a comparative study of syntax, semantics, and pragmatics. It also examines major programming paradigms: object-oriented, imperative, functional, and logic.

**CMP SCI 4280 Program Translation:** 3 semester hours
Prerequisites: CMP SCI 2700, CMP SCI 2750, CMP SCI 3130, and CMP SCI 4250, or graduate standing. This course focuses on methods, techniques, and mechanisms used to create the abstraction from high level programming to machine level execution. Using program translation as an example of a complex task, this course also teaches how to manage and develop solutions for complex programming problems using modular incremental development and testing using an individual semester long project.

**CMP SCI 4300 Introduction to Artificial Intelligence:** 3 semester hours
Prerequisites: CMP SCI 3130. This course provides an introduction to artificial intelligence. The list of topics may include search, planning, knowledge-based reasoning, probabilistic inference, machine learning, natural language processing, and practical applications. Credit cannot be granted for both CMP SCI 4300 and CMP SCI 5300.

**CMP SCI 4320 Introduction to Evolutionary Computation:** 3 semester hours
Prerequisites: CMP SCI 2261, CMP SCI 2750 and CMP SCI 3130. This course introduces the concepts of nature-inspired problem solving with artificial evolution using selection, crossover, mutation and inheritance. It discusses applications of evolutionary algorithms, overviews the existing models and instances, and analyzes specific instances such as genetic algorithms, evolutionary programming, evolution strategies, and genetic programming. Credit not granted for both CMP SCI 4320 and CMP SCI 5320.

**CMP SCI 4340 Introduction to Machine Learning:** 3 semester hours
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course provides an introduction to machine learning in the context of applications such as data mining, natural language processing, and adaptive computer systems. The course reviews several supervised, unsupervised, and reinforcement machine learning techniques such as naive Bayes networks, clustering, and decision trees. Selected concepts in computational learning theory may also be covered. Credit cannot be granted for both CMP SCI 4340 and CMP SCI 5340.
**CMP SCI 4342 Introduction to Data Mining: 3 semester hours**  
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course provides an introduction to data mining principles, algorithms and applications. Topics may include data preprocessing, data transformation, similarity and dissimilarity measures, data representation, classification techniques, association analysis, cluster analysis, regression, dimension reduction, and anomaly detection. Credit not granted for both CMP SCI 4342 and CMP SCI 5342.

**CMP SCI 4370 Introduction to Biological Data Science: 3 semester hours**  
Prerequisites: CMP SCI 3130 or consent of instructor. This course provides an introduction into several key areas of biological data science, with a focus upon genetic data. Relevant background topics in genetics, current issues, and a variety of available resources will be explored. Upon successful completion of this course, the student will be able to evaluate algorithms for analyzing genetic data, including assessments of sources of errors and analysis of time and space complexity; address shortcomings in existing approaches; and implement efficient and effective software for exposing information hidden in genetic data. Credit cannot be granted for both CMP SCI 4370 and CMP SCI 5370.

**CMP SCI 4390 Introduction to Deep Learning: 3 semester hours**  
Prerequisites: CMP SCI 3130 or consent of instructor. This course introduces mathematical foundations for deep learning, and follows with practical applications using selected domains such as image classification or protein predictions. It also covers dense neural networks, convolutional neural networks, recurrent neural networks, and other state-of-the-art networks. Credit cannot be granted for both CMP SCI 4390 and CMP SCI 5390.

**CMP SCI 4410 Introduction to Computer Graphics: 3 semester hours**  
Prerequisites: CMP SCI 2250 and MATH 2450. This course covers the theoretical foundation and algorithms for computer graphics. Students learn the basics of graphics programming for modeling, rendering, and animation of 2D and 3D objects, using standard graphics API. A brief discussion of special graphics hardware, such as GPU, may be included. Credit cannot be granted for both CMP SCI 4410 and CMP SCI 5410.

**CMP SCI 4420 Introduction to Digital Image Processing: 3 semester hours**  
Prerequisites: MATH 1900, MATH 2450, CMP SCI 2750, and CMP SCI 3130. This course focuses on image analysis and visual perception. Students learn data structures and algorithms for image processing, region and texture analysis, image filtering, edge detection, contour following, and image enhancement in both spatial and frequency domain. Other topics may include color processing, coding for storage, retrieval, transmission, and image restoration. Credit cannot be granted for both CMP SCI 4420 and CMP SCI 5420.

**CMP SCI 4500 Introduction to the Software Profession: 3 semester hours**  
Prerequisites: CMP SCI 2261, CMP SCI 3010, and MATH 3000. This course focuses on software development and on the skills required for success in the software profession. Topics related to software development may include software process, models and views, software architectures, documentation, and testing strategies. Topics related to the profession may include ethics, licensing, copyright, trademarks, and professional conduct. Individual and group projects, research, and presentations may be required in this capstone course.

**CMP SCI 4520 Introduction to Object-Oriented Analysis and Design: 3 semester hours**  
Prerequisites: CMP SCI 2261 and CMP SCI 3130. This course covers object-oriented development, using UML and following an agile process. It discusses elements of analysis, requirements, design, implementation and deployment, such as use cases, static and dynamic models, patterns, and frameworks. This course includes a semester long project. Credit not granted for both CMP SCI 4520 and CMP SCI 5520.

**CMP SCI 4610 Database Management Systems: 3 semester hours**  
Prerequisites: CMP SCI 3101 and MATH 3000; or graduate standing. This course focuses on database theory and applications, with emphasis on the relational model. Topics include database design, modeling, file systems, indexing, integrity constraints, relational algebra, normalization, transaction processing, and concurrency control. Students are exposed to emerging DBMS technologies and applications. Several programming projects will be required using a popular SQL server.

**CMP SCI 4700 Computer Forensics: 3 semester hours**  
Prerequisites: CMP SCI 2750 and CMP SCI 3010; or graduate standing. This course explores topics and methodologies for examining digital evidence, along with some principles of the investigative process. Includes memory, file system, operating system, network, and mobile device forensics. This course addresses both theory and hands-on aspects for conducting digital forensic examinations.

**CMP SCI 4730 Computer Networks and Communications: 3 semester hours**  
Prerequisites: CMP SCI 2750 and MATH 1320; or graduate standing. This course provides a broad overview of computer networks and communications. Covers the fundamental principles and protocols across the whole layering structure of the Internet protocol stack. A top-down approach covers multiple topics including network application layer, transport layer, network layer, link layer, and physical layer protocols. May also include a range of related technologies such as WWW, HTTP, FTP, DNS, SMTP, TCP, UDP, ICMP, IPv4, IPv6, OSPF, RIP, BGP, IEEE 802.11 (WiFi), cellular networks, LANs, Ethernet, CSMA/CD, CDMA, multimedia networking, network management, and security in Internet.

**CMP SCI 4732 Introduction to Cryptography for Computer Security: 3 semester hours**  
Prerequisites: MATH 3000 or consent of instructor. This course provides an introduction to cryptography as it applies to computer security. It describes cryptographic code-making and code-breaking, and how they are integrated within larger security systems. Topics include symmetric encryption algorithms like AES, asymmetric encryption using prime number factorization and elliptic curves, message authentication codes, key exchange protocols and attacks on all these systems. Additional topics may include onion networks and blockchain technology, as well as possible attacks on those systems. Credit cannot be granted for more than one of CMP SCI 4732, CMP SCI 4780, and CMP SCI 5732.

**CMP SCI 4740 Introduction to High Performance Computing: 3 semester hours**  
Prerequisites: CMP SCI 2750 and CMP SCI 3130. This course introduces algorithms for multiprocessor and multi-core architectures. Students learn the models of modern parallel computation and techniques to take advantage of parallel architectures for distributed and shared memory multi-processor architectures. Credit not granted for both CMP SCI 4740 and CMP SCI 5740.
**CMP SCI 4750 Introduction to Cloud Computing: 3 semester hours**
Prerequisites: CMP SCI 2750. This course provides an introduction to development and deployment of applications in the cloud space. Touches on different aspects of cloud computing such as IaaS, PaaS, and SaaS. Includes significant discussion on legal and security aspects of clouds in the marketplace. May also include public, private, and hybrid clouds, and Internet of Things. Credit not granted for both CMP SCI 4750 and CMP SCI 5750.

**CMP SCI 4760 Operating Systems: 3 semester hours**
Prerequisites: CMP SCI 2750 and CMP SCI 3130; or graduate standing. This course covers the structure of a generic operating system, considering in detail the algorithms for interprocess communication, process scheduling, resource management, memory management, file systems, and device management. It presents examples from contemporary operating systems and requires practical projects implemented within a modern operating system or simulator environment.

**CMP SCI 4770 Computer and Network Security: 3 semester hours**
Prerequisites: CMP SCI 4730 or graduate standing. This course provides a broad overview of computer and network security technologies and concerns from multiple perspectives, such as cryptography, Public Key Infrastructures (PKI), hashes and message digests, computer viruses and malware, email security, TCP/IP security, IPSec, Secure Socket Layer (SSL), Transport Layer Security (TLS), Virtual Private Networks (VPN), Firewall, AAA (Authentication, Authorization, Accounting), wireless and mobile systems security, secure identifications (IDs), cloud security, privacy and integrity, network attacks, system monitoring, and Intrusion Detection System (IDS). Management and human factors related to security will also be discussed.

**CMP SCI 4782 Information Security: 3 semester hours**
Prerequisites: CMP SCI 4730 or CMP SCI 4732 or CMP SCI 4780 or consent of instructor. This course covers topics related to maintaining security in an organizational infrastructure, including risk analysis of the environment, access level and control including multi-factor authentication, and detection capabilities to ensure adequate security monitoring. Additional topics may include network level protections, firewalls, intrusion detection/prevention systems, securing web and mobile applications, securing cloud implementations, and overall architectural considerations for system security. Credit not granted for both CMP SCI 4782 and CMP SCI 5782.

**CMP SCI 4792 Mobile and Ubiquitous Computing: 3 semester hours**
Prerequisites: CMP SCI 4730 or consent of instructor. This course covers mobile and wireless networking and provides a comprehensive treatment of wireless data and telecommunication networks. Topics include recent trends in mobile and wireless networking, wireless coding and modulation, wireless signal propagation, wireless local area networks, millimeter wave gigabit wireless networks, vehicular wireless networks, white spaces, Bluetooth and Bluetooth Smart, wireless personal area networks, wireless protocols for Internet of Things (IoT), and cellular networks.

**CMP SCI 4880 Individual Studies: 1-3 semester hours**
Prerequisites: Consent of instructor. This course allows a student to pursue individual studies under the supervision of a faculty member. It may include development of a software project. The course may be repeated for credit.

**CMP SCI 4890 Topics in Computer Science: 3 semester hours**
Prerequisites: Consent of the Instructor. This course covers a special topic in computer science to be determined by recent developments in the field and the interests of the instructor. This course may be taken for credit more than once so long as the topic discussed in each semester is different.

**CMP SCI 5012 Enterprise Web Development: 3 semester hours**
Prerequisites: CMP SCI 4010 or consent of instructor. Covers design and implementation issues for enterprise web development, and some popular advanced technologies. Topics include MVC and persistence frameworks, such as Spring and Hibernate. Other topics may include Java Web services, EJB, messaging standards such as JMS, and Java EE design patterns. Students will develop enterprise-level web application projects. Credit cannot be earned for both CMP SCI 4012 and CMP SCI 5012.

**CMP SCI 5020 Android Apps: Android Fundamentals: 3 semester hours**
Prerequisites: CMP SCI 4010 or consent of instructor. Covers the fundamental programming principles, software architecture and user experience considerations underlying handheld software applications and their development environments. Involves in-depth, hands-on examples, implemented on the Android Platform, and discussion of security. Credit not granted for both CMP SCI 4020 and CMP SCI 5020.

**CMP SCI 5030 Intelligent Web: 3 semester hours**
Prerequisite: Graduate standing. This course covers the application of artificial intelligence and other modern techniques to help construct, navigate, and experience the Web. Topics may include retrieval models, classification, mining, association, topology, and indexing algorithms such as PageRank and HITS. Credit cannot be earned for both CMP SCI 4030 and CMP SCI 5030.

**CMP SCI 5130 Advanced Data Structures and Algorithms: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course covers analysis of time and space complexity of iterative and recursive algorithms along with performance bounds, design of data structures for efficient performance, sorting algorithms, probabilistic algorithms, divide and conquer strategies, various algorithms on graphs, and np completeness.

**CMP SCI 5222 Advanced iOS Apps: 3 semester hours**
Prerequisites: CMP SCI 4220 or consent of instructor. Focuses on building sophisticated apps using iOS. Will cover recent developments in networking such as web services, Bluetooth and wifi connectivity, graphics and animation in 2-d and 3-d, autolayouts, OpenGL, advanced data sources such as plist and core data, source control and unit testing. May also discuss security topics. Credit not granted for both CMP SCI 4222 and CMP SCI 5222.

**CMP SCI 5300 Artificial Intelligence: 3 semester hours**
Prerequisites: Graduate standing. This course provides an introduction to artificial intelligence. The list of topics may include search, planning, knowledge-based reasoning, probabilistic inference, machine learning, natural language processing, and practical applications. Credit cannot be granted for both CMP SCI 4300 and CMP SCI 5300.

**CMP SCI 5320 Evolutionary Computation: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course introduces the concepts of nature-inspired problem solving with artificial evolution using selection, crossover, mutation and inheritance. It discusses applications of evolutionary algorithms, overviews the existing models and instances, and analyzes specific instances such as genetic algorithms, evolutionary programming, evolution strategies, and genetic programming. Credit not granted for both CMP SCI 4320 and CMP SCI 5320.
**CMP SCI 5340 Machine Learning: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course provides an introduction to machine learning in the context of applications such as data mining, natural language processing, and adaptive computer systems. The course reviews several supervised, unsupervised, and reinforcement learning techniques such as naive Bayes networks, clustering, and decision trees. Selected concepts in computational learning theory may also be covered. Credit cannot be granted for both CMP SCI 4340 and CMP SCI 5340.

**CMP SCI 5342 Data Mining: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course provides an introduction to data mining principles, algorithms and applications. Topics may include data preprocessing, data transformation, similarity and dissimilarity measures, data representation, classification techniques, association analysis, cluster analysis, regression, dimension reduction, and anomaly detection. Credit not granted for both CMP SCI 4342 and CMP SCI 5342.

**CMP SCI 5370 Biological Data Science: 3 semester hours**
Prerequisites: Graduate standing in Computer Science or consent of instructor. This course provides an introduction into several key areas of biological data science, with a focus upon genetic data. Relevant background topics in genetics, current issues, and a variety of available resources will be explored. Upon successful completion of this course, the student will be able to evaluate algorithms for analyzing genetic data, including assessments of sources of errors and analysis of time and space complexity; address shortcomings in existing approaches; and implement efficient and effective software for exposing information hidden in genetic data. Credit cannot be granted for both CMP SCI 4370 and CMP SCI 5370.

**CMP SCI 5390 Deep Learning: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course reviews a typical machine learning recipe, mathematical foundations for deep learning, and provides an introduction to deep learning. Topics include dense neural networks, convolutional neural networks, and recurrent neural networks. The course will cover building, training, and using deep neural networks for solving various machine learning problems like image classification and protein contact prediction. Credit cannot be granted for both CMP SCI 4390 and CMP SCI 5390.

**CMP SCI 5410 Computer Graphics: 3 semester hours**
Prerequisites: Graduate standing in Computer Science. This course covers the theoretical foundation and algorithms of computer graphics. Students learn the basics of graphics programming for modeling, rendering, and animation of 2D and 3D objects, using standard graphics API. A brief discussion of special graphics hardware, such as GPU, may be included. Credit cannot be granted for both CMP SCI 4410 and CMP SCI 5410.

**CMP SCI 5420 Digital Image Processing: 3 semester hours**
Prerequisites: Graduate Standing in Computer Science. This course focuses on image analysis and visual perception. Students learn data structures and algorithms for image processing, region and texture analysis, image filtering, edge detection, contour following, and image enhancement in both spatial and frequency domain. Other topics may include color processing, coding for storage, retrieval, transmission, and image restoration. Credit cannot be granted for both CMP SCI 4420 and CMP SCI 5420.

**CMP SCI 5500 Software Engineering: 3 semester hours**
Prerequisite: Graduate standing. Introduces software engineering as a discipline, discusses stages of the software life cycle, compares development models such as waterfall, prototyping and incremental/iterative, covers requirements analysis, effort and cost estimation, compares structured and object-oriented analysis and design methods. Discusses verification/validation, quality assurance, software reliability, testing methods, maintenance, documentation, project management and team structure, metrics, and available tools.

**CMP SCI 5520 Object Oriented Analysis and Design: 3 semester hours**
Prerequisite: Graduate Standing in Computer Science. This course covers object-oriented development, illustrated with a visual modeling language and following an agile process. Discusses elements of analysis, requirements, design, implementation, and deployment such as use cases, static and dynamic diagrams, patterns, and frameworks. This course includes a semester long project starting with requirements and culminating with deployment. Credit not granted for both CMP SCI 4520 and CMP SCI 5520.

**CMP SCI 5620 Intelligent Information Retrieval: 3 semester hours**
Prerequisites: CMP SCI 4300 or CMP SCI 5300. This course studies techniques for analysis of information by statistical, syntactical, and logical methods. Topics related to multimedia information are also discussed.

**CMP SCI 5700 Computer Systems: 3 semester hours**
Prerequisite: Graduate standing in Computer Science. This course focuses on parallel computing architectures, including RISC, pipelining, vector processing, SIMD, MIMD, and array processing. It introduces different memory and I/O subsystems, hardware description languages, and it demonstrates performance enhancement using different architectures studied.

**CMP SCI 5732 Cryptography for Computer Security: 3 semester hours**
Prerequisites: Graduate standing. This course provides an introduction to cryptography as it applies to computer security. It describes cryptographic code-making and code-breaking, and how they are integrated within larger security systems. Topics include symmetric encryption algorithms like AES, asymmetric encryption using prime number factorization and elliptic curves, message authentication codes, key exchange protocols and attacks on all these systems. Additional topics may include onion networks and blockchain technology, as well as possible attacks on those systems. Credit cannot be grant for more than one of CMP SCI 4732, CMP SCI 4780, and CMP SCI 5732.

**CMP SCI 5740 High Performance Computing: 3 semester hours**
Prerequisite: Graduate Standing in Computer Science. This course introduces algorithms for multiprocessor and multi-core architectures. Students learn the models of modern parallel computation and techniques to take advantage of parallel architectures for distributed and shared memory multi-processor architectures. Credit not granted for both CMP SCI 4740 and CMP SCI 5740.

**CMP SCI 5750 Cloud Computing: 3 semester hours**
Prerequisites: Graduate standing. Provides an introduction to development and deployment of applications in the cloud space. Touches on different aspects of cloud computing such as IaaS, PaaS, and SaaS. Includes significant discussion on legal and security aspects of clouds in the marketplace. May also include public, private, and hybrid clouds, and Internet of Things. Credit not granted for both CMP SCI 4750 and CMP SCI 5750.
CMP SCI 5782 Advanced Information Security: 3 semester hours
Prerequisites: CMP SCI 4730 or CMP SCI 4732 or CMP SCI 4780 or CMP SCI 5732 or consent of instructor. The topics covered in this course are risk analysis to understand the security requirements of an environment; access controls to understand the level of controls needed for different practical situations, including multi-factor authentication; detection capabilities, to ensure adequate security monitoring for information systems; network level protections, with firewalls, intrusion detection/prevention systems; securing the web and mobile applications and cloud implementations; and overall security architecture to understand how various controls can provide the security-in-depth that is required in the current environment. Credit not granted for both CMP SCI 4782 and CMP SCI 5782.

CMP SCI 5794 Security of IoT Systems: 3 semester hours
Prerequisites: CMP SCI 4730 or consent of the department. This course covers the cutting-edge techniques on the emerging edge cloud and wireless/mobile Internet of Things (IoT) systems. It covers the IoT reference architecture, integrated IoT security architecture, major threats and vulnerabilities with the IoT devices and edge cloud, and defense mechanisms. It includes hands-on labs on both the vulnerabilities and defense of the systems. Credit cannot be granted for both CMP SCI 4794 and CMP SCI 5794.

CMP SCI 5870 Computer Science Seminar: 1-3 semester hours
Prerequisites: Graduate standing. This is a seminar on various topics. Substantial student reading and participation is expected. It may be taken more than once for credit with the consent of the department.

CMP SCI 5880 Computer Science Independent Project: 1-3 semester hours
Prerequisites: Graduate standing and consent of instructor. This course offers the student an opportunity to work on an advisor-supervised project, individually or in a group. A student may repeat the course for up to 6 credit hours total, but at most 6 hours can be accumulated for CMP SCI 5880 and CMP SCI 6900.

CMP SCI 5890 Topics in Computer Science: 1-3 semester hours
Prerequisites: Graduate standing. This course offers various topics not offered on a regular basis. This course may be taken for credit more than once so long as the topic discussed in each semester is different.

CMP SCI 5900 Graduate Internship in Computer Science: 3 semester hours
Prerequisites: Consent of Advisor. The internship provides for a student to attain field experience in an organization related to Computer Science. A student is employed off-campus for an assignment of at least 320 hours working on a project as directed by his/her supervisor in the host organization. The project should be approved by the student's academic advisor, or a designated faculty member, who will monitor the student's progress. The student is responsible for having the project supervisor at the company establish contact with the academic advisor to establish schedule and goals, and a procedure to evaluate the goals. The student will submit a written report to the advisor at the end of internship. The course cannot be repeated for credit. Students completing this course will be allowed only up to three hours of Independent Study (CMP SCI 5880).

CMP SCI 6320 Advances in Evolutionary Computation: 3 semester hours
Prerequisites: CMP SCI 5320. This course focuses on some advanced topics in genetic and evolutionary computation (both theory and applications). Topics may include genetic algorithm variants, intelligent metaheuristics, evolutionary machine learning, differential evolution, swarm intelligence, learning classifier systems, and Markov models. A substantial part of the course will be based on selected topics from recent literature. This is a project-based course, with the project typically involving literature search and conducting and reporting research. Projects may involve developing specific applications or implementing a specific model.

CMP SCI 6340 Genetic Programming: 3 semester hours
Prerequisites: CMP SCI 5320. This course provides an in-depth exploration of Genetic programming, including advanced concepts such as scalability, evolution of modularity and regularity, and constrained evolution with CGP, STGP, or CFG-based GP. It may be reading, research, or application oriented.

CMP SCI 6410 Topics in Computer Graphics: 3 semester hours
Prerequisites: CMP SCI 4410 or CMP SCI 5410. This course covers various aspects of advanced graphics techniques, such as geometric modeling, rendering, shading, texturing, and computer animation. The course provides an in-depth study of recent advanced topics in computer graphics.

CMP SCI 6420 Topics In Image Processing and Multimedia: 3 semester hours
Prerequisites: CMP SCI 5420. This course covers new developments in digital image processing, computer vision, and multimedia. Topics to be covered may include image databases, object tracking, and large-scale data visualization.

CMP SCI 6490 Thesis: 1-6 semester hours
Prerequisites: Completion of at least 12 graduate credits and approval of research topic by thesis advisor. This course is designed for those students intending to present a thesis as part of their M.S. program. At most 6 hours can be accumulated for CMP SCI 5880 and CMP SCI 6900.