Computer and Information Sciences

Prospective students should use this checklist (http://www.uab.edu/graduate/images/acrobat/checklist/cis.pdf) to obtain specific admissions requirements on how to apply to Graduate School.

Degree Offered: Ph.D., M.S.
Director: Dr. Chengcui Zhang
Phone: (205) 934-8606
E-Mail: czhang02@uab.edu
Web site: https://cis.uab.edu/graduate

Program Information
The field of computer and information sciences deals with theory and methods for processing of information. Graduate programs leading to the M.S. and Ph.D. degrees are designed to prepare individuals for professional and research-level careers in industry, government, and academia. Prospective students should have substantial background in computer science and mathematics.

M.S. Programs
The M.S. (https://cis.uab.edu/academics/graduates) program requires 24 semester hours of coursework plus 6 semester hours of thesis research and a thesis (Plan I) or 30 semester hours of coursework (Plan II). Specializations are available in bioinformatics, computer graphics, and distributed computing. CIS and JS (Dept. of Justice Sciences) also jointly offer the MS in Computer Forensics and Security Management (https://cis.uab.edu/academics/graduates/master-program/computer-forensics-and-security-management). For details, please check the department website (https://cis.uab.edu).

Ph.D. Program
The Ph.D. program consists of three phases (with some overlap between phases). The first phase of the program is devoted primarily to formal coursework and preparation for the qualifying examination. The second phase consists of coursework and research in preparation for the comprehensive examination. This examination requires presentation of a dissertation research proposal. Successful completion of this phase leads to admission to candidacy. The final phase is the completion of the dissertation research and its defense. Ph.D. student progress will be reviewed annually.

Application Deadlines
- Masters Program in Computer and Information Sciences: April 15 for Fall; October 1 for Spring.
- Masters Program in Computer Forensics and Security Management: March 1 for Summer; June 1 for Fall; November 1 for Spring.
- Doctoral Program in Computer and Information Sciences: January 15 for Fall; September 1 for Spring.

Contact Information
For detailed information, after first visiting the website below for basic information including application guidelines and prerequisites, contact Dr. Chengcui Zhang, Associate Professor and Graduate Program Director, UAB Department of Computer and Information Sciences, Campbell Hall, Room 127, 1300 University Boulevard, Birmingham, Alabama 35294-1170.

Telephone 205-934-8606
E-mail czhang02@uab.edu (puri@uab.edu)
Web cis.uab.edu/graduate

Courses
CS 501. Programming Languages. 3 Hours.
Study major programming paradigms, their realization in programming languages, and their impact on application design and implementation. Prerequisites: CS 550 [Min Grade: C]

CS 501L. Programming Languages Laboratory. 0 Hours.
Laboratory to accompany CS501.

CS 510. Database Management Systems. 3 Hours.
Relational model of databases, structured query language, normalized structure of database management systems based on relational model, and security and integrity of databases.

CS 514. Digital Documents, Security & Intellectual Property. 3 Hours.
To investigate and research various topics in information security that apply to intellectual property and digital documents. This is a required course for the Master of Science in Computer Forensics and Security Management. This course is not available for credit to students pursuing the MS and Ph.D. Degree in Computer and Information Sciences.

CS 516. Practical Overview of Computer Security (POCS). 3 Hours.
Overview of the information required to obtain an ISC2 security certification with focus on the 10 domains of the CISSP examination (which are representative of what every practicing computer security professional must know). Provides students with a breadth-oriented review of Computer Security practice. This is a required course for the Master of Science in Computer Forensics and Security Management. This course is not available for credit to students pursuing the MS and Ph.D. Degree in Computer and Information Sciences.

CS 518. Computer Forensics Practicum. 3 Hours.
This is the practicum in which every MS CFSM student undertakes a 3-hour internship (approximately 10hrs per week) in the field. This is a required course for the Master of Science in Computer Forensics and Security Management. This course is not available for credit to students pursuing the MS and Ph.D. Degree in Computer and Information Sciences. Master of CFSM Students are expected to be within 9 hours of completing their degree before signing up for this practicum.

CS 519. Investigating Online Crimes. 3 Hours.
Introduction to cyber-investigative techniques involving network forensics, using automated methods to evaluate digital evidence from network packet captures, emails, server logs, and security event logs related to cyber crime cases. This course is not available for credit to students pursuing the MS and Ph.D. Degree in Computer and Information Sciences.

CS 520. Software Engineering. 3 Hours.
Design and implementation of large-scale software systems, software development life cycle, software requirements and specifications, software design and implementation, verification and validation, project management and team-oriented software development.

CS 520L. Software Engineering Laboratory. 0 Hours.
Laboratory to accompany CS520.
CS 533. Operating Systems. 3 Hours.
Internal design and operation of a modern operating system, including interrupt handling, process scheduling, memory management, virtual memory, demand paging, file space allocation, file and directory management, file/user security and file access methods. Computer Networks.

CS 533L. Operating Systems Laboratory. 0 Hours.
Laboratory to accompany CS 533.

CS 534. Networking. 3 Hours.

CS 534L. Networking Laboratory. 0 Hours.
Project oriented hands-on approach.

CS 537. Cybercrime and Forensics. 3 Hours.
A hands-on course covering all aspects of "media forensics" faced by Computer Forensics Examiners. Students will learn to analyze character encoding, file formats, and digital media, including hard drives and smartphones, as well as disk acquisition and duplication techniques and how to apply these techniques in typical criminal investigation scenarios.

CS 550. Automata and Formal Language Theory. 3 Hours.
Finite-state automata and regular expressions, context-free grammars and pushdown automata, turing machines, computability and decidability, and complexity classes.

CS 555. Probability & Statistics in CS. 3 Hours.

CS 591. Special Topics. 1-3 Hour.
Selected Topics in Computer Science.

CS 592. Special Topics. 1-3 Hour.
Selected Topics in Computer Science.

CS 597. Competitive Programming Techniques. 1 Hour.
This course will help students become more competitive in a programming competition such as the ACM programming contest by exploring numerous problem solving techniques and algorithms not covered in the traditional curriculum.

CS 598. Practical Work Experience. 1,3 Hour.
Credit for working in the Computer Science field. Does not count toward M.S. degree.

CS 600. Formal Semantics of Programming Languages. 3 Hours.
Context-sensitive and semantic aspects of programming languages, denotational semantics, mathematical foundations.

CS 601. Program Verification. 3 Hours.
Proving properties of programs, termination and correctness, computability and decidability, role of formal methods in software design.

CS 602. Compiler Design. 3 Hours.
Lexical and syntactical scan, semantics, code generation and optimization, dataflow analysis, parallelizing compilers, automatic compiler generation, and other advanced topics.
Prerequisites: CS 505 [Min Grade: B]

CS 610. Database Systems I. 3 Hours.
This course offers an introduction to the advanced topics of database management systems. The following topics are addressed: System and file structure, efficient data manipulation using indexing and hashing, query processing, crash recovery, concurrency control, transaction processing, database security and integrity, distributed databases.
Prerequisites: CS 510 [Min Grade: B]

CS 611. Database Systems II. 3 Hours.
Relational, hierarchical, and network models; object-oriented databases, knowledge-based systems; security issues, concurrency control and distributed databases, query optimization; advanced topics.
Prerequisites: CS 610 [Min Grade: B]

CS 612. Knowledge-Based Systems. 3 Hours.
Logic model for deductive databases, top-down and bottom-up evaluation, conjunctive and disjunctive queries, recursion, query optimization, universal relation model.
Prerequisites: CS 610 [Min Grade: B]

CS 613. Object-Oriented Database Systems. 3 Hours.
Object data model, object-oriented query languages and database architecture, schema evolution, integration with non-object-oriented models, query optimization.
Prerequisites: CS 610 [Min Grade: B]

CS 614. Distributed Database Systems. 3 Hours.
Distributed DBMS architecture, query decomposition and data localization, distributed query optimization, transaction management, concurrency control, multidatabase systems.
Prerequisites: CS 610 [Min Grade: B]

CS 615. Multimedia Databases. 3 Hours.
This course introduces the principles of multimedia databases including multimedia information processing, modeling, and retrieval. The media to be considered include text, image, audio and video. At the conclusion of this course, the students should understand what multimedia data retrieval is, the principles, which allow the location of relevant information from amongst a large corpus of multimedia data, and the applications of multimedia information retrieval. The students should also have the expertise and competence to design and implement retrieval software for multimedia data.
Prerequisites: CS 610 [Min Grade: C]

CS 616. Big Data Programming. 3 Hours.
Introduction to Big Data, Properties of Big Data, platforms, programming models, applications, business analytics programming, big data processing with Python, R, and SAS, MapReduce programming with Hadoop.

CS 617. Database Security. 3 Hours.
Database fundamentals, introduction to database security, overview of security models, access control models, covert channels and inference channels, MySQL security, Oracle security, Oracle label security, developing a database security plan, SQL server security, security of statistical databases, security and privacy issues of data mining, database applications security, SQL injection, defensive programming, database intrusion prevention, audit, fault tolerance and recovery, Hippocratic databases, XML security, network security, biometrics, cloud database security, big database security.
CS 620. Advanced Software Engineering. 3 Hours.
Advanced topics in software design, including: Software modularization, design patterns, formal methods, and software testing.
Prerequisites: CS 520 [Min Grade: B]

CS 621. Advanced Web Application Development. 3 Hours.
Introduction to web application design and development. Includes traditional web applications utilizing server-side scripting as well as client/ server platforms. Covers responsive design for both mobile and desktop users, as well as hands on server provisioning and configuration. Other topics include web security problems and practices, authentication, database access, application deployment and Web API design, such as REpresentational State Transfer (REST).

CS 621L. Advanced Web Application Development Laboratory. 0 Hours.
Laboratory to accompany CS 621.

CS 622. Reflective and Adaptive Systems. 3 Hours.
This course examines the principles of compile-time and run-time adaptation in several contexts, including: reflection, metaprogramming, aspect-oriented software development, and metamodelling (applied to model-driven engineering).

CS 623. Network Security. 3 Hours.
Conventional network security (symmetric and public-key cryptography). Message encryption and authentication. Secure communication between computers in a hostile environment, including E-mail (PGP), virtual private networks (IPSec), remote access (SSH), and E-commerce (SSL), firewalls, intrusion detection and prevention, security of IEEE 802.11 wireless networks (WEP, WPA), Mandatory weekly Linux-based lab.

CS 623L. Network Security Laboratory. 0 Hours.
Laboratory to accompany CS 623.

CS 624. Formal Specification of Software Systems. 3 Hours.
Formal methods for software requirements specification, including VDM, Z, and object-oriented extensions; the relationship among formal requirements, design, and implementation.
Prerequisites: CS 505 [Min Grade: B]

CS 625. Metrics and Performance. 3 Hours.
Computer Systems addressed in this course primarily are web based systems and capacity planning is a principal theme. However, the queueing theory and statistical analysis approaches are applicable to conventional computing systems and, in fact, modeling of these latter constitute relevant background information that is developed and exploited for web systems analysis.

CS 626. Secure Software Development. 3 Hours.
Why and how software fails, characteristics of secure and resilient software, life cycle of secure software development, metrics and models for secure software maturity, design methodology, best practices for secure programming, secure software for mobile computing, cloud computing and embedded systems, methodology for testing and validation.

CS 629. Software Engineering Research Project. 1-3 Hours.
This is a project-based experimental research course affiliated with the Masters Specialization in Software Engineering. Can only be taken as part of a specialization in Software Engineering.

CS 630. Computer Architecture. 3 Hours.
Introduction to computer architecture, including memory subsystems, direct-mapped and set-associative cache and multi-level cache subsystems, direct-access devices including RAID and SAS disk drives, processor pipelining including super-scalar and vector machines, parallel architectures including SMP, NUMA and distributed memory systems, Interrupt mechanisms, and future microprocessor design issues.

CS 631. Distributed Systems. 3 Hours.
Object-oriented distributed systems design, distributed software architecture, data and resource access, communication, client-server computing, web technologies, enterprise technologies.

CS 632. Parallel Computing. 3 Hours.
Overview of parallel computing hardware, architectures, & programming paradigms; parallel programming using MPI, Pthreads, and OpenMP; design, development, and analysis of parallel algorithms for matrix computations, FFTs, and Sorting.

CS 633. Cloud Computing. 3 Hours.
Introduction to cloud computing, definition, history, models of service delivery, IaaS/PaaS/SaaS clouds, Public/private/Hybrid clouds, cloud architectures, cloud storage, data center design issues, cloud programming systems, MapReduce programming, security and privacy issues, application development on commercial Cloud Computing Platforms, building mobile apps with a cloud based backend, using cloud APIs in PaaS/IaaS/SaaS platforms.

CS 634. Virtualization. 3 Hours.
Theory and practice of virtualization. Origins, history, technical and economic motivations. Relationship to network operating systems and operating system architecture. Simulation, Emulation, Virtualization of CPUs, networks, storage, desktops, memory, devices, and combinations thereof. Different approaches to virtualization, including hardware assists and software-only techniques. Techniques, approaches, and methodologies for scale-out and scale-up computing, including security, performance and economic concerns.

CS 635. Network Programming. 3 Hours.
Remote procedure call and client-server mechanisms. Protocol definition and compilation; client and server stubs and application code; transport independence; multiple client and server systems. Applications, e.g., remote database query and update and image filtering and archiving; systems programming and file systems contexts.

CS 636. Computer Security. 3 Hours.
Study of the breadth of major computer security topics including cyber threats, malware, information assurance, authorization, applied cryptography, web security, mobile and wireless security, network security, systems/software security, database and storage security, user-centered security, and best security practices and countermeasures.

CS 639. Distributed Computing Research Project. 1-3 Hour.
Project based course using distributed parallel computing techniques. Can only be taken as part of a specialization in Distributed Computing.

CS 640. Bioinformatics I. 3 Hours.
Introduction to computational methodologies in bioinformatics.

CS 641. Bioinformatics II. 3 Hours.
Introduction to computational methodologies in bioinformatics.
Prerequisites: CS 640 [Min Grade: B]
CS 642. Mobile and Wireless Security. 3 Hours.
Mobile/wireless devices are ubiquitous, raising the potential for many cyber threats. This course examines security vulnerabilities inherent in many existing and emerging mobile and wireless systems, ranging from smartphones to wearables and RFID tags. In addition to exposing security vulnerabilities, defensive mechanisms to address these vulnerabilities drawn from existing deployments and research literature will be studied.

CS 643. Cloud Security. 3 Hours.
Definition of cloud computing, cloud computing models, privacy, authenticity and integrity of outsourced data, proof of data possession / retrievability, cloud forensics, malware analysis as a service, remote verification of capability and reliability, proof of availability, economic attacks on clouds and outsourced computing, virtual machine security, trusted computing technology and clouds, verifiable resource accounting, cloud-centric regulatory compliance issues and mechanisms, business and security risk models, secure MapReduce, applications of secure cloud computing, private information retrieval and cloud cartography.

CS 645. Modern Cryptography. 3 Hours.
Theory and practices of modern cryptographic techniques, algorithms and protocols, including formal analysis. Secret key encryption algorithms, public key encryption algorithms, stream ciphers, one-way hashing algorithms, authentication and identification, digital signatures, signcryption, key establishment and management, secret sharing and data recovery, zero-knowledge proofs, public key infrastructures, efficient implementation, cryptanalytic attacks and countermeasures, security models, assumptions and proofs.

CS 646. Digital Currency. 3 Hours.
Fundamental principles of digital cash systems including Bitcoin, Ripple and other notable cryptocurrencies. Topics to be covered include how a cryptocurrency works, blockchain and other decentralized consensus protocols, proof of work, proof of stake, security and privacy of cryptocurrencies, cryptographic techniques for digital currency, and applications of blockchain in peer-to-peer trust establishment, smart contracts, digital asset management, financial exchanges and distributed autonomous organization.

CS 647. Biomedical Modeling. 3 Hours.
Modeling from biomedical datasets. Acquisition, segmentation; registration and fusion; construction of shame models; measurement; illustration modeling techniques for surgical planning.

CS 649. Bioinformatics Research Project. 1-3 Hour.
Can only be taken as part of a specialization in Bioinformatics.

CS 650. Automata Languages and Computation. 3 Hours.
Formal grammars and automata, Turing machines, computability and decidability, computational complexity, intractability.
Prerequisites: CS 550 [Min Grade: B]

CS 651. Formal Language Theory. 3 Hours.
Parsing and translation theory, formal syntax, proof properties and complexity measures.

CS 652. Design/Analysis of Algorithms. 3 Hours.
Overview of the primary techniques used in the mathematical analysis of algorithms. The focus is on “average-case” or “probabilistic” analysis.

CS 653. Computational Geometry. 3 Hours.
Basic methods and data structures, geometric searching, convex hulls, proximity, intersections.

CS 654. Malware Analysis. 3 Hours.
Hands-on course teaching static, dynamic and contextual analysis of malware. Malware analysis, and investigation is taught through interaction with both “classroom” and “wild” malware samples. Defensive and counter-measure techniques for both corporate and law enforcement environments are explored.

CS 656. Web Security. 3 Hours.
The web uses advanced applications that run on a large variety of browsers that may be built using programming languages such as JavaScript, AJAX, Google Web Toolkit and Apache Struts, to name a few. This course studies how core web technologies work, the common security vulnerabilities associated with them, and how to build secure web applications that are free from these vulnerabilities.

CS 657. Penetration Testing and Vulnerability Assessment. 3 Hours.
This course focuses on penetration testing and vulnerability analysis. It introduces methodologies, techniques and tools to analyze and identify vulnerabilities in stand-alone and networked applications. It also covers methodologies for legal and standards compliance.

CS 659. Multiprocessor Programming. 3 Hours.
This course examines synchronization in concurrent systems, available atomic primitives, non-blocking programming techniques, lock-/wait-freedom, transactional memory, and memory models in hardware and software. The application of these techniques to the development of scalable data structures for multi-core architectures will be a central topic of this course.

CS 660. Artificial Intelligence. 3 Hours.
Programming methodologies, logic foundations, natural language applications, expert systems.

CS 661. Expert Systems. 3 Hours.
Concepts and architectures, tools, reasoning, evaluations, selected examples.

CS 662. Natural Language Processing. 3 Hours.
Syntax, semantics, ATNs, logic grammars, language and memory.

CS 663. Knowledge Discovery and Data Mining. 3 Hours.
Techniques used in data mining (such as frequent sets and association rules, decision trees, Bayesian networks, classification, clustering), algorithms underlying these techniques, and applications.

CS 664. Knowledge Representation. 3 Hours.
Logic, production systems, semantic nets, frames, multiple representational systems.

CS 665. Neural Networks. 3 Hours.
Theoretical foundations, associative memory, pattern processing, biological neural nets.

CS 666. Machine Learning. 3 Hours.
Introduction to machine learning, the design of algorithms that can make predictions about the future based on past experience. Emphasizes practical considerations for developing efficient and accurate machine learning models, and theoretical underpinnings of different learning algorithms.
Prerequisites: CS 660 [Min Grade: C]

CS 669. Introduction to the Internet of Things. 3 Hours.
Definition of the Internet of Things (IoT), history, IoT components, device specifications and examples, architectures, protocols, applications, security and privacy issues, programming and development environments for IoT, interoperability, interfacing IoT devices via web and mobile applications.
CS 670. Computer Graphics. 3 Hours.
Graphics architectures, geometric transforms, 3-D, object models, shading, intensity, hidden elements, color, advanced topics.

CS 671. Shape Design. 3 Hours.
This course covers various aspects of the design of mathematical descriptions of shape. These geometric models are used in computer graphics, game design, automobile and aircraft design, robotics, anatomical modeling, and many other disciplines. Building geometry from images. Bezier and B-spline curves and surfaces.

CS 672. Geometric Modeling for Computer Graphics. 3 Hours.
The formal description of a motion is necessary in computer animation for graphics, game design, robotics, and many other disciplines. This course covers various aspects of the design of motions. Typical topics include position control along Bezier curves, orientation control with quaternion splines, motion planning, motion capture, camera control, collision detection, visibility analysis.

CS 673. Computer Vision. 3 Hours.
Image smoothing and filtering, feature detection, segmentation, calibration and alignment, object recognition, morphology, projective geometry, scale space.

CS 674. 3D Printing. 3 Hours.
3D Printing: design, materials, and aesthetics. Students will do projects which result in unique artifacts created by 3D printing. Multi-disciplinary teams are encouraged.

CS 675. Visualization. 3 Hours.
Advanced Computer Graphics techniques aimed at "Scientific Visualization" applications.

CS 676. Structure from Motion. 3 Hours.
Structure from motion extracts geometric information from a series of images of an object, either still photographs or video streams. The position of the camera may also be computed, yielding camera paths. This topic has powerful applications in many areas, including computer graphics, computer vision, photography, visualization, and video augmentation. Projective geometry, multiple view geometry, feature extraction.

Can only be taken as part of a specialization in Computer Graphics.

CS 680. Numerical Computing Foundations. 3 Hours.
Matrix computations, matrix analysis, solution of linear systems, nonlinear systems, spectral analysis, least squares.

CS 681. Simulation Models. 3 Hours.
Model development using popular simulation languages, e.g., Excel or OpenOffice.org Calc Spreadsheet; interfacing to an animation system such as Proof Animation or Open_GL.

CS 682. Simulation Methodology. 3 Hours.
Combined continuous and discrete simulation, simulation theory, modeling environments.

CS 683. Open Source Security Systems. 3 Hours.
An introduction to the design, implementation, evaluation and maintenance of secure software systems and applications using open source technologies, with an emphasis on hands-on experience. Topics include: open source ecosystems, open source security methodologies and models, notable open source software systems and projects, quality and security assurance through open source, open source supply chain security, major open source cryptographic packages; designing, implementing and maintaining security systems using open source technologies; assessment and regulatory compliance using open source tools, and open source hardware.

CS 684. Robot Motion. 3 Hours.
Path planning algorithms. Configuration space, potential functions, roadmaps, cell decomposition, probabilistic motion planning, compliant motion.

CS 690. Special Topics. 1-3 Hour.
Selected topics in Computer Science.

CS 691. Special Topics. 1-3 Hour.
Selected topics in Computer Science.

CS 692. Special Topics. 1-3 Hour.
Selected topics in Computer Science.

CS 697. Directed Readings. 1-6 Hour.
Selected readings, research and project development under direction of a faculty member. Must have permission of instructor and graduate program director.

CS 698. Master's Plan II. 1-9 Hour.
Masters student registration.

CS 699. Master's Thesis Research. 1-6 Hour.
Research for M.S. candidates writing a thesis.

Prerequisites: GAC M

CS 700. Formal Semantics of Programming Languages. 2,3 Hours.
Context-sensitive and semantic aspects of programming languages, denotational semantics, mathematical foundations.

CS 701. Program Verification. 3 Hours.
Proving properties of programs, termination and correctness, computability and decidability, role of formal methods in software design.

CS 702. Compiler Design. 3 Hours.
Lexical and syntactical scan, semantics, code generation and optimization, dataflow analysis, parallelizing compilers, automatic compiler generation, and other advanced topics.

CS 710. Database Systems I. 3 Hours.
This course offers an introduction to the advanced topics of database management systems. The following topics are addressed: System and file structure, efficient data manipulation using indexing and hashing, query processing, crash recovery, concurrency control, transaction processing, database security and integrity, distributed databases.

CS 711. Database Systems II. 3 Hours.
Relational, hierarchical, and network models; object-oriented databases, knowledge-based systems; security issues, concurrency control and distributed databases, query optimization; advanced topics.

CS 712. Knowledge-Based Systems. 3 Hours.
Logic model for deductive databases, top-down and bottom-up evaluation, conjunctive and disjunctive queries, recursion, query optimization, universal relation model.
CS 713. Object-Oriented Database Systems. 3 Hours.
Object data model, object-oriented query languages and database architecture, schema evolution, integration with non-object-oriented models, query optimization.

CS 714. Distributed Database Systems. 3 Hours.
Distributed DBMS architecture, query decomposition and data localization, distributed query optimization, transaction management, concurrency control, multidatabase systems.

CS 715. Multimedia Databases. 3 Hours.
This course introduces the principles of multimedia databases including multimedia information processing, modeling, and retrieval. The media to be considered include text, image, audio and video. At the conclusion of this course, the students should understand what multimedia data retrieval is, the principles, which allow the location of relevant information from amongst a large corpus of multimedia data, and the applications of multimedia information retrieval. The students should also have the expertise and competence to design and implement retrieval software for multimedia data.

Prerequisites: CS 303 [Min Grade: B]

CS 716. Big Data Programming. 3 Hours.
Introduction to Big Data. Properties of Big Data, platforms, programming models, applications, business analytics programming, big data processing with Python, R, and SAS, MapReduce programming with Hadoop.

CS 717. Database Security. 3 Hours.
Database fundamentals, introduction to database security, overview of security models, access control models, covert channels and inference channels, MySQL security, Oracle security, Oracle label security, developing a database security plan, SQL server security, security of statistical databases, security and privacy issues of data mining, database applications security, SQL injection, defensive programming, database intrusion prevention, audit, fault tolerance and recovery, Hippocratic databases, XML security, network security, biometrics, cloud database security, big database security.

CS 720. Advanced Software Engineering. 3 Hours.
Advanced topics in software design, including: Software modularization, design patterns, formal methods, and software testing.

CS 722. Reflective and Adaptive Systems. 3 Hours.
This course examines the principles of compile-time and run-time adaptation in several contexts, including: reflection, metaprogramming, aspect-oriented software development, and metamodeling (applied to model-driven engineering).

CS 723. Network Security. 3 Hours.
Conventional network security (symmetric and public-key cryptography). Message encryption and authentication. Secure communication between computers in a hostile environment, including E-mail (PGP), virtual private networks (IPSec), remote access (SSH), and E-commerce (SSL), firewalls, intrusion detection and prevention, security of IEEE 802.11 wireless networks (WEP, WPA). Mandatory weekly Linux-based lab.

CS 723L. Network Security Laboratory. 0 Hours.
Laboratory to accompany CS 723.

CS 724. Formal Specification of Software Systems. 3 Hours.
Formal methods for software requirements specification, including VDM, Z, and object-oriented extensions; the relationship among formal requirements, design, and implementation.

CS 725. Metrics and Performance. 3 Hours.
Computer Systems addressed in this course primarily are web based systems and capacity planning is a principal theme. However, the queueing theory and statistical analysis approaches are applicable to conventional computing systems and, in fact, modeling of these latter constitute relevant background information that is developed and exploited for web systems analysis.

CS 726. Secure Software Development. 3 Hours.
Why and how software fails, characteristics of secure and resilient software, life cycle of secure software development, metrics and models for secure software maturity, design methodology, best practices for secure programming, secure software for mobile computing, cloud computing and embedded systems, methodology for testing and validation.

CS 730. Computer Architecture. 3 Hours.
Introduction to computer architecture, including memory subsystems, direct-mapped and set-associative cache and multi-level cache subsystems, direct-access devices including RAID and SCSI disk drives, processor pipelining including super-scalable and vector machines, parallel architectures including SMP, NUMA and distributed memory systems, Interrupt mechanisms, and future microprocessor design issues.

CS 731. Distributed Systems. 3 Hours.
Object-oriented distributed systems design, distributed software architecture, data and resource access, communication, client-server computing, web technologies, enterprise technologies.

CS 732. Parallel Computing. 3 Hours.
Overview of parallel computing hardware, architectures, & programming paradigms; parallel programming using MPI, Pthreads, and OpenMP; design, development, and analysis of parallel algorithms for matrix computations, FFTs, and Sorting.

CS 733. Cloud Computing. 3 Hours.
Introduction to cloud computing, definition, history, models of service delivery, IaaS/PaaS/SaaS clouds, Public/private/Hybrid clouds, cloud architectures, cloud storage, data center design issues, cloud programming systems, MapReduce programming, security and privacy issues, application development on commercial Cloud Computing Platforms, building mobile apps with a cloud based backend, using cloud APIs in PaaS/IaaS/SaaS platforms.

CS 734. Virtualization. 3 Hours.
Theory and practice of virtualization. Origins, history, technical and economic motivations. Relationship to network operating systems and operating system architecture. Simulation, Emulation, Virtualization of CPUs, networks, storage, desktops, memory, devices, and combinations thereof. Different approaches to virtualization, including hardware assists and software-only techniques. Techniques, approaches, and methodologies for scale-out and scale-up computing, including security, performance and economic concerns.

CS 735. Network Programming. 3 Hours.
Remote procedure call and client-server mechanisms. Protocol definition and compilation; client and server stubs and application code; transport independence; multiple client and server systems. Applications, e.g., remote database query and update and image filtering and archiving; systems programming and file systems contexts.
CS 736. Computer Security. 3 Hours.
Study of the breadth of major computer security topics including
cyber threats, malware, information assurance, authorization, applied
cryptography, web security, mobile and wireless security, network
security, systems/software security, database and storage security, user-
centered security, and best security practices and countermeasures.

CS 739. Distributed Computing Research. 3 Hours.
Project based course using distributed parallel computing techniques.

CS 740. Bioinformatics I. 3 Hours.
Introduction to computational methodologies in bioinformatics.

CS 741. Bioinformatics II. 3 Hours.
Introduction to computational methodologies in bioinformatics.

CS 742. Mobile and Wireless Security. 3 Hours.
Mobile/wireless devices are ubiquitous, raising the potential for many
cyber threats. This course examines security vulnerabilities inherent
in many existing and emerging mobile and wireless systems, ranging
from smartphones to wearables and RFID tags. In addition to exposing
security vulnerabilities, defensive mechanisms to address these
vulnerabilities drawn from existing deployments and research literature
will be studied.

CS 743. Cloud Security. 3 Hours.
Definition of cloud computing, cloud computing models, privacy,
authenticity and integrity of outsourced data, proof of data possession /
retrievability, cloud forensics, malware analysis as a service, remote
verification of capability and reliability, proof of availability, economic
attacks on clouds and outsourced computing, virtual machine security,
trusted computing technology and clouds, verifiable resource accounting,
cloud-centric regulatory compliance issues and mechanisms, business
and security risk models, secure MapReduce, applications of secure
cloud computing, private information retrieval and cloud cartography.

CS 745. Modern Cryptography. 3 Hours.
Theory and practices of modern cryptographic techniques, algorithms
and protocols, including formal analysis. Secret key encryption
algorithms, public key encryption algorithms, stream ciphers, one-way
hashing algorithms, authentication and identification, digital signatures,
signcryption, key establishment and management, secret sharing and
data recovery, zero-knowledge proofs, public key infrastructures, efficient
implementation, cryptanalytic attacks and countermeasures, security
models, assumptions and proofs.

CS 746. Digital Currency. 3 Hours.
Fundamental principles of digital cash systems including Bitcoin, Ripple
and other notable cryptocurrencies. Topics to be covered include
how a cryptocurrency works, blockchain and other decentralized
consensus protocols, proof of work, proof of stake, security and privacy
of cryptocurrencies, cryptographic techniques for digital currency, and
applications of blockchain in peer-to-peer trust establishment, smart
contracts, digital asset management, financial exchanges and distributed
autonomous organization.

CS 747. Biomedical Modeling. 3 Hours.
Modeling from biomedical datasets. Acquisition, segmentation;
registration and fusion; construction of shape models; measurement;
illustration modeling techniques for surgical planning.

CS 750. Automata, Languages & Computation. 3 Hours.
Formal grammars and automata, Turing machines, computability and
decidability, computational complexity, intractability.

CS 751. Formal Language Theory. 3 Hours.
Parsing and translation theory, formal syntax, proof properties and
complexity measures.

CS 752. Design and Analysis of Algorithms. 3 Hours.
Overview of the primary techniques used in the mathematical analysis of
algorithms. The focus is on “average-case” or “probabilistic” analysis.

CS 753. Computational Geometry. 3 Hours.
Basic methods and data structures, geometric searching, convex hulls,
proximity, intersections.

CS 756. Web Security. 3 Hours.
The web uses advanced applications that run on a large variety of
browsers that may be built using programming languages such as
JavaScript, AJAX, Google Web Toolkit and Apache Struts, to name a
few. This course studies how core web technologies work, the common
security vulnerabilities associated with them, and how to build secure web
applications that are free from these vulnerabilities.

CS 757. Penetration Testing and Vulnerability Assessment. 3 Hours.
This course focuses on penetration testing and vulnerability analysis. It
introduces methodologies, techniques and tools to analyze and identify
vulnerabilities in stand-alone and networked applications. It also covers
methodologies for legal and standards compliance.

CS 759. Multiprocessor Programming. 3 Hours.
This course examines synchronization in concurrent systems, available
atomic primitives, non-blocking programming techniques, lock/wait-
freedom, transactional memory, and memory models in hardware and
software. The application of these techniques to the development of
scalable data structures for multi-core architectures will be a central topic
of this course.

CS 760. Artificial Intelligence. 3 Hours.
Programming methodologies, logic foundations, natural language
applications, expert systems.

CS 761. Expert Systems. 3 Hours.
Concepts and architectures, tools, reasoning, evaluations, selected
elements.

CS 762. Natural Language Processing. 3 Hours.
Syntax, semantics, ATNs, logic grammars, language and memory.

CS 763. Knowledge Discovery and Data Mining. 3 Hours.
Techniques used in data mining (such as frequent sets and association
rules, decision trees, Bayesian networks, classification, clustering),
algorithms underlying these techniques, and applications.

CS 764. Knowledge Representation. 3 Hours.
Logic, production systems, semantic nets, frames, multiple
representational systems.

CS 765. Neural Networks. 3 Hours.
Theoretical foundations, associative memory, pattern processing,
biological neural nets.

CS 767. Machine Learning. 3 Hours.
Introduction to machine learning, the design of algorithms that can make
predictions about the future based on past experience. Emphasizes
practical considerations for developing efficient and accurate machine
learning models, and theoretical underpinnings of different learning
algorithms.

Prerequisites: CS 760 [Min Grade: C]

CS 769. Introduction to the Internet of Things. 3 Hours.
Definition of the Internet of Things (IoT), history, IoT components, device
specifications and examples, architectures, protocols, applications,
security and privacy issues, programming and development environments
for IoT, interoperability, interfacing IoT devices via web and mobile
applications.
CS 770. Computer Graphics. 3 Hours.
Graphics hardware, raster images, color, shading, ray casting, triangle meshes, coordinate frames, transformation matrices, perspective and orthographic viewing, rasterization, depth buffer, animation, quaternions, smooth curves (B-spline, Bezier) and surfaces, sampling, texture mapping, graphics programming.

CS 771. Shape Design. 3 Hours.
This course covers various aspects of the design of mathematical descriptions of shape. These geometric models are used in computer graphics, game design, automobile and aircraft design, robotics, anatomical modeling, and many other disciplines. Building geometry from images. Bezier and B-spline curves and surfaces.

CS 772. Geometric Modeling for Computer Graphics. 3 Hours.
The formal description of a motion is necessary in computer animation for graphics, game design, robotics, and many other disciplines. This course covers various aspects of the design of motions. Typical topics include position control along Bezier curves, orientation control with quaternion splines, motion planning, motion capture, camera control, collision detection, visibility analysis.

CS 773. Computer Vision. 3 Hours.
Image smoothing and filtering, feature detection, segmentation, calibration and alignment, object recognition, morphology, projective geometry, scale space.

CS 774. 3D Printing. 3 Hours.
3D Printing : design, materials, and aesthetics. Students will do projects which result in unique artifacts created by 3D printing. Multi-disciplinary teams are encouraged.

CS 775. Visualization. 3 Hours.
Advanced Computer Graphics techniques aimed at "Scientific Visualization" applications.

CS 776. Structure from Motion. 3 Hours.
Structure from motion extracts geometric information from a series of images of an object, either still photographs or video streams. The position of the camera may also be computed, yielding camera paths. This topic has powerful applications in many areas, including computer graphics, computer vision, photography, visualization, and video augmentation. Projective geometry, multiple view geometry, feature extraction.

CS 780. Numerical Computing Foundations. 3 Hours.
Matrix computations and matrix analysis, including solution of linear systems, solution of nonlinear systems, spectral analysis, quadrature, and least squares.

CS 781. Simulation Models and Animations. 3 Hours.
Model development using popular simulation languages, e.g., Excel or OpenOffice.org Calc Spreadsheet; interfacing to an animation system such as Proof Animation or Open_GL.

CS 782. Simulation Methodology. 3 Hours.
Combined continuous and discrete simulation, simulation theory, modeling environments.

CS 783. Open Source Security Systems. 3 Hours.
An introduction to the design, implementation, evaluation and maintenance of secure software systems and applications using open source technologies, with an emphasis on hands-on experience. Topics include: open source ecosystems, open source security methodologies and models, notable open source software systems and projects, quality and security assurance through open source, open source supply chain security, major open source cryptographic packages; designing, implementing and maintaining security systems using open source technologies; assessment and regulatory compliance using open source tools, and open source hardware.

CS 784. Robot Motion. 3 Hours.
Path planning algorithms. Configuration space, potential functions, roadmaps, cell decomposition, probabilistic motion planning, compliant motion.

CS 790. Special Topics. 3 Hours.
Selected Topics in Computer Science.

CS 791. Special Topics. 3 Hours.
Selected Topics in Computer Science.

CS 792. Special Topics. 3 Hours.
Selected Topics in Computer Science.

CS 796. Directed Readings and Research. 1-9 Hour.
Selected readings, research and project development under direction of a faculty member. Must have permission of instructor and graduate program director.

Prerequisite: Admission to candidacy.
Prerequisites: GAC D