

Lane Department of Computer Science and Electrical Engineering

Degrees Offered

- Masters of Science, Computer Science (M.S.C.S.)
- Masters of Science, Electrical Engineering (M.S.E.E.)
- Masters of Science, Software Engineering (M.S.S.E.)
- Doctor of Philosophy, Computer Engineering (Ph.D.)
- Doctor of Philosophy, Electrical Engineering (Ph.D.)
- Doctor of Philosophy, Computer Science (Ph.D.)

Graduate Certificates Offered

- Graduate certificate in software engineering
- Graduate certificate in computer forensics
- Graduate certificate in biometrics & information assurance
- Graduate certificate in interactive technologies & serious gaming

Overview of Programs

The Lane Department of Computer Science and Electrical Engineering offers master's programs leading to a master's of science in computer science (M.S.C.S.), a master's of science in electrical engineering (M.S.E.E.), and a master's of science in software engineering (M.S.S.E.). It also participates in the College of Engineering and Mineral Resources interdisciplinary program offering the master's of science in engineering (M.S.E.). Master of science students must comply with the rules for master's degrees as set forth by the college in the Guidelines for Masters Degree Programs Offered in the College of Engineering and Mineral Resources and by the Department in the Masters of Science Program Guidelines.

The department also offers programs leading to the doctor of philosophy (Ph.D.) in computer science and the doctor of philosophy (Ph.D.) in engineering with specialization in electrical engineering or computer engineering. Ph.D. in electrical or computer engineering students must comply with the rules set forth by both the College's Doctor of Philosophy Program Guidelines and by the Department in the Doctor of Philosophy Program Guidelines. Ph.D. students in computer and information sciences must comply with the rules set forth in the Handbook for Computer Science Graduate Students.

The department also offers four graduate certificates which may be completed as part of a degree program or as a certificate only.

Program Educational Objectives and Outcomes

The common educational objectives of all the graduate programs in the Lane Department is to produce graduates who have the knowledge, skills, and attitudes that will ensure success in professional positions in business, industry, research, government service, or in further graduate or professional study. The requirements and outcomes of specific degree and certificate programs are described in the catalog pages specific to those programs.

Facilities and Centers

The Lane Department of CSEE has its main office, instructional lab, and research lab space on the Evansdale campus occupying four floors of the Engineering Sciences Building and one floor of the Engineering Research Building. The department also has facilities located in Armstrong Halls on the downtown campus.

The department is home to two university research centers: the Center for Identification Technology Research (CITeR), which is designated an Industry/University Cooperative Research Center by the National Science Foundation; and the Center for Advanced Power & Energy Research (APEREC). The university is also designated as a Center of Excellence in Information Assurance Research by the National Security Agency and Department of Homeland Security. The department and college host a modern 4,000 square foot clean room facility for device and sensor fabrication, under the management of the university's Shared Research Facilities. The university is also home to an outstanding set of faculty-led laboratory facilities, in areas that include electronic and photonic material, biometrics, communications, digital and analog signal processing, power electronics, robotics, high reliability software, computer security, computer forensics, artificial intelligence, virtual environments, theoretical computer science, and electric vehicles.

All graduate students have access to a broad variety of computing platforms for both classwork and research. The department operates and maintains a variety of dedicated computer systems, clusters, and networks supporting both the instructional and research activities of the department. These systems include numerous Windows workstations and a cluster of Linux Servers. An additional laboratory by Hewlett-Packard supports large databases and medical informatics. Students have access to a rich set of software packages and tool suites available either on department systems or the College of Engineering and Mineral Resources systems. All department, college, and university computing resources are fully networked via Ethernet and FDDI with a campus-wide ATM backbone enabling interface to the statewide ATM network. All computing systems have internet access enabling

worldwide connectivity and access to several additional computing services via the Pittsburgh Supercomputing Center. The university is also a member of Internet2, of which faculty in the department are active participants.

Areas of Research

The department is enthusiastically and vigorously involved in research, technical publication, and graduate instruction at the forefront of the field. Academic and research activity is organized into five areas:

- Electronics and photonics
- Systems and signals
- Computer systems
- Software and knowledge engineering
- Theory of computation

FACULTY

CHAIR

- Brian Woerner - Ph.D. (Purdue University)
Wireless Communications and Networking

PROFESSORS

- Donald Adjeroh - Ph.D. (Chinese University of Hong Kong)
Graduate Coordinator for Computer Science, Multimedia Information Systems (Image, Video, and Audio), Distributed Multimedia Systems
- Hany Ammar - Ph.D. (University of Notre Dame)
Risk Assessment, Software Engineering, Biometrics, Performance and Dependability Analysis, Modeling and Evaluation of Parallel and Distributed Systems
- Muhammad Choudhry - Ph.D. (Purdue University)
Graduate Coordinator for CpE & EE, Power System Control, DC Transmission, Stability, Power Electronics
- Parviz Famouri - Ph.D. (University of Kentucky)
Analysis and Control of Electrical Machines, Motor Drives, Power Electronics, Electric Vehicles
- Ali Feliachi - Ph.D. (Georgia Institute of Technology)
Power Systems, Large-Scale Systems, Control
- Powsiri Klinkhachorn - Ph.D. (West Virginia University)
Microprocessor Applications, Computer Architecture, Binary and Non-Binary Logic
- Dimitris Korakakis - Ph.D. (Boston University)
Semiconductor Growth, Nanotechnology, Photonic Devices, Biosensors
- Afzel Noore - Ph.D. (West Virginia University)
VLSI Design and Testing, Software Engineering, Information Assurance and Biometrics
- Roy Nutter Jr. - Ph.D., P.E. (West Virginia University)
Neural Networks, Microprocessor Systems, Computer Architecture, Computer Forensics
- Y. Ramana Reddy - Ph.D. (West Virginia University)
Artificial Intelligence, Knowledge-based Simulation, Computer Graphics
- Krishnamurthy Subramani - Ph.D. (University of Maryland)
Scheduling, Computational Biology, Computational Complexity, Polyhedral Combinatorics
- Matthew Valenti - Ph.D. (Virginia Polytechnic Institute and State University)
Communication Theory, Wireless Systems, Error Control Coding

ASSOCIATE PROFESSORS

- Xian-An Cao - Ph.D. (University of Florida)
Nanofabrication, Opto-electronic Devices
- Elaine Eschen - Ph.D. (Vanderbilt University)
Graduate Coordinator for CS Ph.D. CCDM Program, Design and Analysis of Algorithms, Graph Theory, Combinatorics
- Katerina Goseva-Popstojanova - Ph.D. (University Sv. Kiril i Metodij)
Software Reliability Engineering, Distributed Systems, Computer Security, Dependability, Performance and Performability Assessment
- David Graham - Ph.D. (Georgia Institute of Technology)
Analog Signal Processing
- Guodong Guo - Ph.D. (University of Wisconsin, Madison)
Computer Vision, Biometrics, Human Computer Interaction

- Mark Jerabek - Ph.D., P.E. (Purdue University)
Solid State Devices and Sensors, Electromagnetics
- Dimitris Korakakis - Ph.D. (Boston University)
Semiconductor Growth, Nanotechnology, Photonic Devices, Biosensors
- Vinodkrishnan Kulathumani - Ph.D. (The Ohio State University)
Wireless Sensor Actuator Networks, Scalable and Fault Tolerant Distributed Systems
- Xin Li - Ph.D. (Princeton University)
Image Processing, Computer Vision, Pattern Recognition
- James Mooney - Ph.D. (Ohio State University)
Associate Chair, Operating Systems, Computer Architecture, Software Portability and Standards, Computer Security and Forensics
- Daryl Reynolds - Ph.D. (Texas A&M)
Statistical Signal Processing for Communications, Iterative (Turbo) Processing, Transmitter Pre-coding, Space-time Coding and Processing
- Natalia Schmid - Ph.D. (Washington University)
Estimation and Detection, Biometrics, Information Theory, Statistical Signal and Image Processing
- Sarika Khushalani Solanki - Ph.D. (Mississippi State University)
Power/Energy Conversion, Power Systems; Controls, Signals, and Systems
- Krishnamurthy Subramani - Ph.D. (University of Maryland)
Scheduling, Computational Biology, Computational Complexity, Polyhedral Combinatorics
- Frances VanScoy - Ph.D. (University of Virginia)
Programming Languages and Compilers, Multisensory Computing, High Performance Computing

ASSISTANT PROFESSORS

- Thirimachos Bourlai - Ph.D. (University of Surrey)
Biomedical Image Processing, Pattern Recognition
- Yuxin Liu - Ph.D. (Louisiana Tech University)
Biotechnology/Bioengineering, BioMEMS and Microfluidics, Cellular Sensor, Tissue Engineering
- Yanfang Ye - Ph.D. (Xiamen University)
Cybersecurity, Machine Learning

RESEARCH ASSOCIATE PROFESSORS

- Alan Barnes - Ph.D. (California Institute of Technology)
Ion Surface Interactions, Materials Growth and Automated Document Analysis
- Sumitra Reddy - Ph.D. (West Virginia University)
Healthcare Informatics, Componentware, Intelligent Systems, Information Technology Evolution

RESEARCH ASSISTANT PROFESSORS

- Jeremy Dawson - Ph.D. (West Virginia University)
Nanotechnology
- Jignesh Solanki - Ph.D. (Pennsylvania State University)
Tissue Engineering, Spinal Cord Injury Repair, Stem Cells, Molecular Neurobiology

VISITING AND ADJUNCT PROFESSORS

- Gyungsu Byun - Ph.D. (University of California, Los Angeles)
Digital Electronic Devices
- Bojan Cukic - Ph.D. (University of Houston)
Software Engineering, High-Assurance Systems, Computational Intelligence, Fault-Tolerant Systems, Biometrics
- Nancy Lan Guo - Ph.D. (West Virginia University)
Medical Information Systems
- Lawrence Hornak - Ph.D. (Rutgers University)
Optics, Integrated Optics, Micro/Nano Structures and Devices, Biosensors, Biometrics
- V. Jagannathan - Ph.D. (Vanderbilt University)
Distributed Intelligent Systems, Internet and Security Technologies
- Tim Menzies - Ph.D. (University of New South Wales)
Software Engineering, Data Mining
- Arun Ross - Ph.D. (Michigan State University)
Statistical Pattern Recognition, Biometrics

- Stephanie Schuckers - Ph.D. (University of Michigan)
Signal Processing, Biometrics

LECTURERS

- Camille Hayhurst - M.S.C.S. (West Virginia University)
Programming Languages
- Raymond Morehead - M.S.C.S. (West Virginia University). M.D. (Northwestern University)
Biomedical Systems, Databases
- Cynthia Tanner - M.S.C.S. (West Virginia University)
Graduate Coordinator for Software Engineering

PROFESSORS EMERITI

- John Atkins - Ph.D. (University of Pittsburgh)
- Wils Cooley - Ph.D., P.E. (Carnegie Mellon University)
- William Dodrill
- Ron Klein - Ph.D. (University of Illinois)
power systems, control, maglev technology
- Robert McConnell - Ph.D. (University of Kentucky)

Admission Requirements for All Programs

All Masters and Ph.D. programs require applicants to provide the items below to be considered for admission. Specific programs may have additional requirements. Exception: These requirements do not apply to nontraditional students in the Certificate of Software Engineering program and M.S.S.E. program (see certificate program and M.S.S.E. program for more information):

- A minimum cumulative grade point average of 3.0 or equivalent, based on a 4.0 system.
- Three letters of reference.
- International students must demonstrate proficiency in communicating in English (a minimum TOEFL Score of 550, or iBT Score of 79, or IELTS Score of 6.5). (Students who have completed a recent four-year bachelor's degree in the USA need not submit these scores.)
- All graduate degree programs require the GRE general test, with a suggested score of either the 80th percentile on the quantitative part or 80th percentile total (verbal + quantitative + analytical).
- All graduate degree programs require an appropriate bachelors or master's degree for entry. Students lacking some foundation courses appropriate to a particular degree program may be assigned some remedial coursework as a condition of admission.
- See: Certificate in Software Engineering; Master of Science in Software Engineering for alternative admission requirements to those programs for working professionals.

Regular, Provisional, and Non-Degree Admission

Students admitted into a program are designated as regular status or provisional. The department also admits students to non-degree status in the College of Engineering and Mineral Resources, but these students are not admitted to any specific program. Regular status is given to students who are qualified for unconditional admission to a specific program. Provisional status is given to students who have deficiencies to make up such as incomplete credentials or other reasons as identified by the graduate coordinator. In all cases, the student's letter of admission will state what must be done to attain regular status.

Provisional students must complete the requirements for transfer to regular status by the end of the semester in which they complete eighteen credit hours. Usually provisional students are not considered for graduate assistantships or tuition waivers.

Non-degree status is granted upon request to students meeting the minimum admission requirements. A non-degree student is one who wishes to take courses without seeking a formal degree. Non-degree students require permission of the instructor to take courses that are restricted to specific majors. There is no guarantee of eventual acceptance into a degree program, and in no case may more than twelve hours be transferred to a degree program.

Non-degree students may not be offered graduate assistantships or tuition waivers.

The Lane Department of Computer Science & Electrical Engineering offers four graduate certificates, which are typically completed as part of a graduate degree program but can be completed as a separate credential. Brief descriptions of the certificate programs are given here. More detailed information on procedures for the certificate programs may be found on the main department web page.

Graduate Certificate in Software Engineering

Details for the Graduate Certificate in Software Engineering are found on the graduate catalog section devoted to the Master of Science in Software Engineering degree program.

Graduate Certificate in Computer Forensics

CERTIFICATE CODE - CG08

The Lane Department of Computer Science and Electrical Engineering (LDCSEE) offers a Graduate Certificate in Computer Forensics (CF). By providing systematic graduate courses in this field, our graduates and others should be better prepared to assist business, industry, government, and academia in attaining a new level of protection from cyber-criminals.

The graduate certificate program consists of fifteen credit hours of required courses. Admission to the graduate certificate program in Computer Forensics requires admission to the M.S. Computer Science or M.S. Electrical Engineering (with Computer Engineering major). One wishing to complete only the Certificate must still be admitted to the M.S.C.S. or M.S.E.E. programs.

The purpose of the certificate program is to:

1. Provide further education to computer professionals with technical undergraduate degrees to enable them to track and protect institutional computer and cyber crime. This knowledge in corporate settings should lead to better protection of company computer assets, company intellectual property, and company data and financial assets. These professionals should be able to support law enforcement in detection and prosecution of cyber-crime when needed.
2. Provide further education for those technical individuals who work in law-enforcement. It is expected that these would be highly technical people with bachelor's degrees in either computer science, computer engineering, or software engineering.

Many (if not most) of the students expected will be full time and pursuing a Masters of Science degrees in Computer Science or Computer Engineering. Other students may come from industry and law enforcement. These students will achieve the Certificate as another resume item that will improve employability while supplying a demand for computer people with such backgrounds. Some students may choose to pursue the Certificate with no intent of completing a Masters degree but will have achieved significant competence in this field.

The Certificate requires fifteen credit hours through required core curriculum courses. In addition to the fifteen credit hours upon course completion, the student will be required to complete a capstone project. The following are the fifteen credits hours:

Required Courses

CPE 435	Computer Incident Response	3
CPE 536	Computer Data Forensics	3
CPE 538	Intro Computer Security Management	3
CS 539	Computer Forensics and the Law	3
CS 568	Computer Network Forensics	3
Total Hours		15

These five courses cover the major areas of study. The first is an overview of the entire area; two will be taught with an emphasis throughout on vulnerabilities and counter-measures. One course emphasizes management practices and oversight required to maintain the best defense against attacks in organizations and how to respond to them. The final course deals with the law and cases governing the area of computer crime, its detection and prosecution, keeping in mind the constraints placed on security by the rights of citizens.

BIOMETRIC SYSTEMS COURSES

BIOM 693. Special Topics. 1-6 Hours.

A study of contemporary topics selected from recent developments in the field.

COMPUTER ENGINEERING COURSES

CPE 520. Application of Neural Networks. 3 Hours.

PR: Consent. Theories, principles, techniques, and procedures used in design implementation of supervised and unsupervised neural networks. Algorithms and computer programming for software realization with engineering applications.

CPE 521. Applied Fuzzy Logic. 3 Hours.

PR: Consent. Theory and applications of fuzzy logic, fuzzy fundamentals, fuzzy rules, decision-making systems, control systems, pattern recognition systems, and advanced topics. Algorithms and computer programming for software realization with engineering applications.

CPE 536. Computer Data Forensics. 3 Hours.

PR: CPE 310 and CPE 435 or Consent. Provides students with a comprehensive overview of collecting, investigating, preserving, and presenting evidence of cybercrime; introduces topics of forensic data examination of computers and other digital storage devices.

CPE 538. Intro Computer Security Management. 3 Hours.

Develops management tools to build and maintain a secure enterprise. Includes policies, procedures, and the various management and auditing processes that are needed in a networked enterprise.

CPE 553. Advanced Networking Concepts. 3 Hours.

PR: Graduate standing. Design and analysis of network protocols; includes the TCP/IP protocol suite, wireless network protocols, mobility management protocols and ad-hoc network protocols; hands-on network programming using TCP/UDP sockets and discrete event simulations.

CPE 568. Computer Network Forensics. 3 Hours.

PR: CS 450 and CS 453 or consent. Introduction to threat assessment in modern networked computer systems. Techniques, methodologies and technologies for preventing, detecting, recovering from and collecting evidence of intrusions, with the intent of prosecuting the offending parties.

CPE 585. Concurrent Programming in Java. 3 Hours.

PR: CS 110 and CS 111 and CS 415 or consent. This is a project-based laboratory-oriented course aimed at learning the fundamentals of component-based software development (CBD) and object-oriented concurrent programming. (OOC) in Java.

CPE 593A-B. Special Topics. 1-6 Hours.

A study of contemporary topics selected from recent developments in the field.

CPE 595. Independent Study. 1-6 Hours.

Faculty supervised study of topics not available through regular course offerings.

CPE 643. Fault Tolerant Computing. 3 Hours.

PR: CPE 310 or Consent. Introduction to reliability analysis and Markov modeling. Computer system reliability modeling. Fault tolerant design of computer systems. Reconfiguration strategies in VLSI and WSI arrays.

CPE 664. Sensor Actuator Networks. 3 Hours.

PR: Graduate standing in CS, CPE, EE or SENG. Introduces students to the state of the art in wireless sensor actuator networks. Provides hands on training in programming these networks.

CPE 670. Switching Circuit Theory 1. 3 Hours.

PR: CPE 271 or equivalent. Course presumes an understanding of the elements of Boolean or switching algebra. Study of both combinational and sequential switching circuits with emphasis on sequential networks. Advanced manual design and computer-aided design techniques for single and multiple output combinational circuits. Analysis and design of sequential circuits. Detection and prevention of undesired transient outputs. (3 hr. rec.).

CPE 684. Advanced Real-Time Systems. 3 Hours.

PR: CS 415 and CPE 484 or consent. Project-based course focused on analysis and design of real-time systems using the unified modeling language. Object-oriented development process based on design patterns and frameworks is described.

CPE 691A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CPE 694. Seminar. 1-6 Hours.

Special seminars arranged for advanced graduate students.

CPE 695. Independent Study. 1-6 Hours.

Faculty supervised study of topics not available through regular course offerings.

CPE 697. Research. 1-15 Hours.

PR: Consent. Research activities leading to thesis, problem report, research paper, equivalent scholarly project, or dissertation. (Grading may be S/U.).

CPE 699. Graduate Colloquium. 1-6 Hours.

PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University's facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

CPE 790. Teaching Practicum. 1-3 Hours.

PR: Consent. Supervised practice in college teaching of computer engineering. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.).

CPE 791A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CPE 792. Directed Study. 1-6 Hours.

Directed study, reading, and/or research.

CPE 793. Special Topics. 1-6 Hours.

A study of contemporary topics selected from recent developments in the field.

CPE 794. Seminar. 1-6 Hours.

Special seminars arranged for advanced graduate students.

CPE 795. Independent Study. 1-9 Hours.

Faculty supervised study of topics not available through regular course offerings.

CPE 796. Graduate Seminar. 1 Hour.

PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

CPE 797. Research. 1-15 Hours.

PR: Consent. Research activities leading to thesis, problem report, research paper, or equivalent scholarly project, or a dissertation. (Grading may be S/U.).

CPE 798. Thesis or Dissertation. 1-6 Hours.

PR: Consent. This is an optional course for programs that wish to provide formal supervision during the writing of student reports (698) or dissertations (798). Grading is normal.

CPE 799. Graduate Colloquium. 1-6 Hours.

PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University's facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not count against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

COMPUTER SCIENCE COURSES**CS 510. Formal Specification of Language. 3 Hours.**

PR: CS 410. Specifications of language syntax and semantics by grammars and automata and by attribute grammars, denotational semantics, and action equations; algebraic, denotational, and operational semantics; application of formal specifications to construction of software tools.

CS 520. Advanced Analysis of Algorithms. 3 Hours.

PR: CS 320. Analysis and design techniques for efficient sequential and parallel algorithm design; NP-completeness, advanced analysis techniques, advanced algorithms, and parallel algorithms.

CS 525. Computational Complexity. 3 Hours.

PR: CS 422. Introduction to the theory of computational complexity. Topics include: turning machines, computability, complexity classes P, NP, and co-NP, the theory of NP-completeness, randomized complexity classes, inapproximability, and complexity classes beyond NP.

CS 530. Formal Methods in Software Engineering. 3 Hours.

PR: CS 430. Principles of rigorous specification, designing, implementation, and validation of sequential, concurrent, and real-time software; emphasis on reading current papers on these topics.

CS 533. Developing Portable Software. 3 Hours.

PR: CS 330 and CS 450 or Consent. Issues, problems, and techniques in the practical development of portable software and in the adaptation of programs to new environments; development of a simple interactive application; porting to several diverse computing platforms.

CS 539. Computer Forensics and the Law. 3 Hours.

PR: CPE 435. Surveys the emerging field of computer law and how it applies to businesses and law enforcement, both to aid and to circumscribe the policies and procedures to tackle computer crime.

CS 540. Theory of Database Systems. 3 Hours.

PR: CS 440. Abstract and newer database models; introduction to database design techniques in the context of semantic data modeling; equivalence of different relational models; object-oriented databases.

CS 550. Theory of Operating Systems. 3 Hours.

PR: CS 450. Theoretical analysis of selected aspects of operating system design; topics include interaction of concurrent processes; scheduling and resource allocation; virtual memory management; access control; and distributed and real-time system issues.

CS 554. Network Computing. 3 Hours.

PR: CS 540 or Consent. An in-depth study of the Internet, networking fundamentals, protocols, algorithms, and principles of distributed computing, introduction to network security and management.

CS 555. Advanced Computer Systems Architecture. 3 Hours.

PR: CS 455 or CPE 442. High performance techniques, pipelined and parallel systems, and high-level architectures; comparative evaluation of architectures for specific applications; emphasis on software implications of hardware specifications.

CS 556. Distributed and Pervasive Compt. 3 Hours.

PR: CS 350 or consent. An in-depth study of distributed computing paradigms, standards, and applications that can exploit this paradigm and the emerging pervasive computing infrastructure.

CS 558. Multimedia Systems. 3 Hours.

PR: CS 350 or EE 465 or consent, requirements and QOS; multimedia data acquisition, object decomposition, multimedia storage servers; multimedia communications-networking, traffic characterizations, traffic scheduling, multicasting; compression of images, video and audio; multimedia information systems-indexing and retrieval of multimedia data.

CS 568. Computer Network Forensics. 3 Hours.

PR: CS 450 and CS 453 or consent. Introduction to threat assessment in modern networked computer systems. Techniques, methodologies and technologies for preventing, detecting, recovering from, and collecting evidence of intrusions, with the intent of prosecuting the offending parties.

CS 569. Cybersecurity and Big Data Analytics. 3 Hours.

PR: Consent. Scientific foundations for solving real-world security problems. Challenges and opportunities of big data. Typical big data analytic and modeling techniques for cybersecurity.

CS 570. Interactive Computer Graphics. 3 Hours.

PR: CS 320. Viewing in three dimensions, projections, rendering of surfaces and solids, illumination and shading, interaction handling, display processors and programming systems, and graphics system organization.

CS 572. Advanced Artificial Intelligence Techniques. 3 Hours.

PR: CS 472. Reasoning under uncertainty; nonmonotonic reasoning, statistical reasoning, fuzzy logic; planning, parallel, and distributed AI, natural language processing, learning, connectionist models, temporal logic, common sense knowledge and qualitative reasoning, AI techniques and robotics.

CS 573. Advanced Data Mining. 3 Hours.

PR: CS 230 and CS 350 or equivalent. We present the theory practice of industrial data mining. Combining pragmatics with theory, students will learn to select appropriate data mining methods for individual applications. Graduate students will learn to conduct data mining experiments.

CS 576. Design of Immersive Media Systems. 3 Hours.

PR: Graduate student status in CS, or consent. Team-based development of a video game, demo reel, or other project demonstrating expertise in game development.

CS 578. Medical Image Analysis. 3 Hours.

PR: EE 465 or equivalent. Advanced topics in medical image analysis, with focus on image restoration, segmentation, registration and visualization.

CS 589. Game Seminar. 1 Hour.

(May be repeated for a maximum of 3 credit hours.) A discussion of current topics in video game development.

CS 591A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CS 592A. Directed Study. 1-6 Hours.

Directed study, reading, and/or research.

CS 593A-Z. Special Topics. 1-6 Hours.

A study of contemporary topics selected from recent developments in the field.

CS 594A. Seminar. 1-6 Hours.

Seminars arranged for advanced graduate students.

CS 595. Independent Study. 1-6 Hours.

Faculty supervised study of topics not available through regular course offerings.

CS 601. Foundations of Software Engineering. 3 Hours.

For CS provisional graduate students only. Object-oriented programming concepts applied to data structures such as queues, lists, trees, techniques, and methods of developing software.

CS 602. Foundations of Algorithms. 3 Hours.

For CS provisional graduate students only. Topics from discrete mathematics including sets, relations, functions, counting principles, graphs and trees, topics from analysis of algorithms including recurrences, sorting, graph and greedy algorithms, and advanced data structures.

CS 604. Semantics of Programming Languages. 3 Hours.

For CS provisional graduate students only. Operating systems, machine organization, number systems and the theoretical and practical aspects of assembler and other programming languages.

CS 623. String Algorithms. 3 Hours.

PR: CS 221 or Consent. Algorithms on strings from traditional combinatorial pattern matchup to recent problems such as suffix sorting and string embeddings. Emphasis is on the data structures and algorithms required, their analysis, and optimal constructions.

CS 630. Empirical Methods in Software Engineering and Computer Science. 3 Hours.

An in-depth study of the scientific process and guidelines for empirical research. Particularly addressing surveys, case studies, and controlled experiments. Covers in detail the qualitative and quantitative data analysis methods commonly used in empirical investigations.

CS 665. Computer System Security. 3 Hours.

PR: CS 465 or Consent. Course describes modern approaches to information and system security including encryption techniques, secure communication protocols, operating system security principles, and network intrusion detection techniques.

CS 674. Computational Photography. 3 Hours.

Computational techniques used for the acquisition and processing of digital photographic data. Introduction to camera technology, image formation, filtering, warping, morphing, compositing, rendering, enhancement, and novel camera design.

CS 676. Machine Learning. 3 Hours.

Principles and techniques used in learning theory, regression, classification, instance-based methods, kernel methods, risk minimization, ensemble-based methods, graphical models, and deep models.

CS 677. Pattern Recognition. 3 Hours.

PR: Consent. Covers salient topics in statistical pattern recognition, including Bayesian decision theory, Bayesian learning and density estimation, linear discriminant functions, multilayer neural networks, support vector machines, and unsupervised learning. Working knowledge of Matlab is essential.

CS 678. Computer Vision. 3 Hours.

An introduction to low-level image analysis methods, image transformations, methods for reconstructing three-dimensional scene information, algorithms for motion and video analysis, and approaches to object recognition.

CS 689. Graduate Internship. 1-3 Hours.

PR: Completion of a minimum of 18 degree applicable graduate credit hours with an overall GPA of 3.0 or better. Employments in industry related to degree program. (Graded P/F. May be repeated twice. Cannot be counted toward graduation requirements.)

CS 690. Teaching Practicum. 1-3 Hours.

PR: Consent. Supervised practice in college teaching of computer science. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It also provides a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

CS 691A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CS 692A. Directed Study. 1-6 Hours.

Directed study, reading, and/or research.

CS 693A-Z. Special Topics. 1-6 Hours.

A study of contemporary topics selected from recent developments in the field.

CS 695. Independent Study. 1-6 Hours.

Faculty supervised study of topics not available through regular course offerings.

CS 696. Graduate Seminar. 1 Hour.

PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

CS 697. Research. 1-15 Hours.

PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

CS 699. Graduate Colloquium. 1-6 Hours.

PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University's facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

CS 726. Algorithmic Graph Theory. 3 Hours.

PR: CS 520 or consent. Introduction to algorithmic graph theory with emphasis on special classes of graphs, graph structure, efficient combinatorial algorithms, graph compositions/ decompositions, and graph representations, current research development trends and open questions on structured families and graphs.

CS 727. Information Dissemination. 3 Hours.

PR: CS 520. Research issues in information dissemination in graphs; emphasis on broadcasting and gossiping algorithms, including identification and solution of open research questions.

CS 736. Software Performance Engineering. 3 Hours.

PR: CS 330 or Consent. A systematic, quantitative approach to cost- effectively constructing software systems that meet performance models; effective data gathering and performance measurement techniques.

CS 740. Advanced Databases Theory. 3 Hours.

PR: CS 540. Design theory for relational databases; functional dependencies; multivalued dependencies and normal forms; projection mappings, tableaux and the chase; representation theory.

CS 750. Secure and Survivable Systems. 3 Hours.

PR: CS 680 or Consent. An in-depth study of principles, standards, practices, and architectures in the area of secure and survivable systems. Case studies, simulations, and games will be used to gain deep understanding of the issues.

CS 751. Digital Enterprises. 3 Hours.

PR: CS 680 or Consent. An in-depth study of principles, standards, practices, and architectures in the area of digital enterprise. Case studies and simulations will be used to gain deep understandings of the issues.

CS 757. Distributed Systems and Algorithms. 3 Hours.

PR: CS 320 and CS 550. Distributed and networked operating systems and the algorithms necessary to achieve such goals as transparency, sharing, fault tolerance, and efficient process and task scheduling.

CS 772. Global Knowledge Networks. 3 Hours.

PR: CS 572. Representational formalisms and effective retrieval techniques to obtain information from international knowledge repositories connected via high-speed networks.

CS 778. Medical Image Analysis. 3 Hours.

Advanced topics in medical image analysis, with focus on image restoration, segmentation, registration and visualization.

CS 790. Teaching Practicum. 1-3 Hours.

PR: Consent. Supervised practice in college teaching of computer science. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.).

CS 791A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CS 792A-Z. Directed Study. 1-6 Hours.

Directed study, reading, and/or research.

CS 793. Special Topics. 1-6 Hours.

A study of contemporary topics selected from recent developments in the field.

CS 794. Seminar. 1-6 Hours.

Special seminars arranged for advanced graduate students.

CS 795. Independent Study. 1-9 Hours.

Faculty supervised study of topics not available through regular course offerings.

CS 796. Graduate Seminar. 1 Hour.

PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

CS 797. Research. 1-15 Hours.

PR: Consent. Research activities leading to thesis, problem report, research paper, or equivalent scholarly project, or a dissertation. (Grading may be S/U.).

CS 798. Thesis or Dissertation. 1-6 Hours.

PR: Consent. This is an optional course for programs that wish to provide formal supervision during the writing of student reports (698), or dissertations (798). Grading is normal.

CS 799. Graduate Colloquium. 1-6 Hours.

PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University's facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

CS 900. Professional Development. 1-6 Hours.

Professional development courses provide skill renewal or enhancement in a professional field or content area (e.g., education community health, geology). The continuing education courses are graded on a pass/fail grading scale and do not apply as graduate credit toward a degree program.

CS 930. Professional Development. 1-6 Hours.

Professional development courses provides skill renewal or enhancement in a professional field or content area (e.g., education, community health, geology). These tuition-waived, continuing education courses are graded on a pass/fail grading scale and do not apply as graduate credit toward a degree program.

ELECTRICAL ENGINEERING COURSES

EE 513. Stochastic Systems Theory. 3 Hours.

PR: Consent. Probability distribution and density functions. Bayes rule and conditional probability. Stochastic process and linear systems. Gauss-Markov Process. Optimal linear estimation. Introduction to Wiener and Kalman filtering. Decision theory fundamentals. (3 hr. rec.).

EE 515. Linear Control Systems. 3 Hours.

PR: Consent. Basic concepts in the theory of linear control systems, state variable representation, solution of state equations, controllability, observability, stability, transfer function descriptions, and design of controllers and observers. (3 hr. rec.).

EE 517. Optimal Control. 3 Hours.

PR: Consent. Methods of direct synthesis and optimization of feedback systems; Wiener theory; Pontryagin's maximum principle; dynamic programming; adaptive feedback systems. (3 hr. rec.).

EE 519. Digital Control. 3 Hours.

PR: EE 411 or Consent. Sampling of continuous-time signals. Transform analysis of discrete-time systems. Translation of analog design. Controllability and observability. State-space design methods and introduction to optimal control for discrete systems. (3 hr. rec.).

EE 528. Biomedical Microdevices. 3 Hours.

Fundamentals of micro-manufacturing and micro-fluidics, microfluidic platforms and components, biosensors, drug-delivery systems, lab-on-a-chip devices, DNA microarrays, emerging applications in biomedicine and tissue engineering, and photolithography and soft lithography lab demonstration.

EE 531. Advanced Electrical Machinery. 3 Hours.

PR: Consent. Theory and modeling of synchronous, induction, and direct-current machines, and their steady-state and transient analysis. (3 hr. rec.).

EE 533. Computer Applications in Power System Analysis. 3 Hours.

PR: EE 436 or Consent. Steady state analysis by digital computers of large integrated electrical power systems. Bus admittance and impedance matrices, load flow studies, economic dispatch and optimal power flow, steady state security analysis, and fault studies. (3 hr. rec.).

EE 535. Power System Control and Stability. 3 Hours.

PR: EE 515. Review of stability theory, classical transient analysis, dynamical models of synchronous machines, power system stability under small and large perturbations, dynamic, and simulation of power systems. (3 hr. rec.).

EE 550. Advanced Semiconductor Electronics. 3 Hours.

PR: EE 450 or equivalent. Theory of electronic and photonic device. Semiconductors properties and their impact on devices behavior - p-n junctions, bipolar transistors, and MOS transistors. Quantum mechanical effects introduced. Development of models to simulate devices and simple circuits.

EE 551. Linear Integrated Circuits. 3 Hours.

PR: EE 355 and EE 356 and EE 450 or equivalent. Design and analysis of analog integrated circuits. Both linear and nonlinear transistor models are covered. Applications focus on linear analog circuits including simple amplifiers, operational amplifiers, and reference circuits. This course focuses on CMOS technology.

EE 561. Communication Theory. 3 Hours.

PR: EE 461 or Consent. Detailed study of probability theory and its use in describing random variables and stochastic processes. Emphasis on applications to problems in communication system design. (3 hr. rec.).

EE 562. Wireless Communication System. 3 Hours.

PR: EE 461 and EE 513. Architecture and design of cellular and wireless communication networks, electromagnetic effects of the wireless channel and corresponding statistical models, implementation and performance of diversity reception techniques, and multiple-access.

EE 564. Digital Signal Processing for Radio Astronomy. 3 Hours.

PR: Graduate Standing and/or consent. Digital signal processing as applied to radio astronomy. Filtering, Fourier transforms and correlation firmware are designed for Field Programmable Gate Arrays.

EE 565. Advanced Image Processing. 3 Hours.

PR: EE 465 or equivalent. Covers the theory of statistically modeling image source, algorithms for analysis and processing of image signals, new applications of image processing into computer vision and biomedical imaging, and MATLAB based image processing.

EE 567. Coding Theory. 3 Hours.

PR: MATH 375 or consent. Design, analysis, and implementation of codes for error detection and correction.

EE 568. Information Theory. 3 Hours.

PR: STAT 215 or equivalent, or consent. Information measures and mutual information; noiseless coding theorem, construction of compact codes and universal codes; channel coding theorem and error correcting codes; cryptography and information theory; algorithmic information theory, and rate distortion theory.

EE 569. Digital Video Processing. 3 Hours.

PR: EE 465. Covers basic theory and algorithmic aspects of digital video processing, along with latest video coding standards, multimedia streaming, security video, and biometrics. Hands-on experience in processing video signals under MATLAB in team-based projects.

EE 591A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 595. Independent Study. 1-6 Hours.

Faculty supervised study of topics not available through regular course offerings.

EE 613. Detection and Estimation Theory. 3 Hours.

PR: EE 513 or equivalent. Study of detection, estimation, and signal representation, detection of signal in noise, estimation of signal parameters, linear estimation theory. Performance bounds on Estimation and Detection. Kalman-Bucy and Wiener filters. Modern optimal estimation and detection.

EE 625. Advanced Signal Processing. 3 Hours.

PR: EE 513 or consent. Statistical aspects of signal processing. Includes advanced techniques, such as autocorrelation/ cross-correlation, autoregressive models, linear prediction, power spectral density, and other topics. Course will contain significant student-driven application component using biomedical, communication, and/or other signals. (3 hr. lec.).

EE 650. Optoelectronics. 3 Hours.

PR: EE 450 or PHYS 471 or consent. Semiconductor physics theory of light-emitting diodes, homojunction lasers, single and double heterojunction lasers, separate confinement quantum well lasers, p-i-n and photo detectors and avalanche photo detectors. Optical and electrical analysis of epitaxial and device designs.

EE 689. Graduate Internship. 1-3 Hours.

PR: Completion of a minimum of 18 degree applicable graduate credit hours with a minimum GPA of 3.0 or better. Employment in industry related to degree program. (Graded P/F. May be repeated twice. Cannot be counted toward graduation requirements.)

EE 691A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 695. Independent Study. 1-6 Hours.

Faculty supervised study of topics not available through regular course offerings.

EE 697. Research. 1-15 Hours.

PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

EE 699. Graduate Colloquium. 1-6 Hours.

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EE 713. Large-Scale System Modeling. 3 Hours.

PR: EE 515. Characterization of large-scale systems, model simplification through aggregation and perturbation methods, optimal and chained aggregation, balanced realization and cost component procedures, optimal model reduction, simplification effects, decentralized control, and feasibility and design. (3 hr. lec.)

EE 731. Real Time Control of Power System. 3 Hours.

PR: EE 515 and EE 517 and EE 533. Application of computers to modern control theory for reliable and economic real-time operation of integrated power systems. (3 hr. rec.)

EE 733. Protection of Power Systems. 3 Hours.

PR: EE 436 or Consent. Principles of relay protection for faults on transmission lines and other devices. Use of overcurrent, differential distance, and pilot relaying systems. Special relay applications. Determination of short-circuit currents and voltages from system studies. (3 hr. rec.)

EE 735. HVDC Transmission. 3 Hours.

PR: EE 435 and EE 533. Line-commutated converter analysis, operation of two terminal and multiterminal dc systems, harmonics and filters, modeling of ac/dc system, and design of modulation controllers.

EE 790. Teaching Practicum. 1-3 Hours.

PR: Consent. Supervised practice in college teaching of electrical engineering. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.)

EE 791A-Z. Advanced Topics. 1-6 Hours.

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PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.)

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SOFTWARE ENGINEERING COURSES**SENG 510. Software Project Management. 3 Hours.**

Techniques and tools for managing the software development process for large development projects.

SENG 520. Software Analysis and Design. 3 Hours.

Defining software requirements and an introduction to the principles and concepts relevant to the design of large programs and software systems.

SENG 530. Validation and Verification. 3 Hours.

Tools and techniques for applied verification and validation of computer software including requirements, design, and code relevant to several development lifecycle models.

SENG 540. Software Evolution. 3 Hours.

Software process and the Capability Maturity Model (CMM), software maintenance and evolution, program understanding, reengineering, software configuration management, and software tools related to these issues.

SENG 550. Object Oriented Design. 3 Hours.

Highlights contemporary design and analysis techniques with a strong emphasis on the Unified Modeling Language(UML). The class focuses on problem space analysis utilizing object oriented techniques to produce real world design solutions in UML.

SENG 560. Software Reuse. 3 Hours.

PR: SENG 550 or consent. A detailed study of the business, organizational, and technical implications of large-scale software reuse in modern environments. Architecture, design for reuse, domain engineering, model-driven development, frameworks, library design, reuse tools, and design patterns.

SENG 561. Agile Software Development. 3 Hours.

PR: SENG 550 or consent. Techniques and methodologies of agile software engineering; development team roles, product backlog, sprint planning, sprint execution, test-driven development, sprint retrospective, development tools and environments. Emphasis on successfully managing agile projects in geographically dispersed work environments.

SENG 564. Software Engineering of Mobile Applications. 3 Hours.

PR: SENG 550 or consent. Software engineering of mobile applications and real-world development of mobile technology. Architecture of a simple mobile application. Industry leaders of mobile software engineering. Mobile economics. Mobile software engineering security practices. Mobile enterprise architectures.

SENG 581. Quality Software Process Management. 3 Hours.

PR: SENG 510 or consent. Evaluate quality theories and practices; research quality history, principles and techniques; and apply software engineering quality management methods and standards to develop software quality model artifacts in an enterprise environment.

SENG 582. Enterprise Architecture Framework. 3 Hours.

PR: SENG 520 or Consent. Study of architecture frameworks used in government and business to design holistic advanced computer systems. Application of frameworks to the enterprise processes, technologies, and people to achieve the enterprise mission and objectives.

SENG 591A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

SENG 610. Advanced Software Project Management. 3 Hours.

PR: SENG 510. Presents best practices for managing software development projects. Addresses leadership, teamwork, issues in modern system development, complexity and its influence on projects, estimating project effort and duration, development of software-intensive systems and systems-of-systems.

SENG 611. Strategies for Software Development. 3 Hours.

PR: SENG 510 or Consent. This course investigates the forces which drive a software organization's business strategy; alignment of a project to the business needs (product line or platform); and the importance of various project management, development and business models.

SENG 630. Requirements Engineering. 3 Hours.

PR: SENG 520 or consent. Study of the requirements engineering phase of the software development process. Techniques for building strong requirements, including management, analysis, risk mitigation, validation, customer signoff, and change control.

SENG 670. Data Analytics with Applications in Software Engineering. 3 Hours.

PR: SENG 520 and STAT 215 or consent. Foundation of data science, with focus on applications in software engineering. Different empirical methods such as surveys, case studies, and experiments. Threats to validity. Methods for data preparation. Statistics for data understanding and assessment. Commonly used supervised and unsupervised machine learning algorithms.

SENG 691A-Z. Advanced Topics. 1-6 Hours.

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

SENG 695. Independent Study. 1-6 Hours.

Faculty supervised study of topics not available through regular course offerings.

SENG 697. Research. 1-15 Hours.

PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U.).