Lane Department of Computer Science and Electrical Engineering

Degrees Offered

- Master of Science, Computer Science (M.S.C.S.)
- Master of Science, Electrical Engineering (M.S.E.E.)
- Master of Science, Software Engineering (M.S.S.E.)
- Master of Science, Engineering (M.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

Overview of Programs

The Lane Department of Computer Science and Electrical Engineering offers master's programs leading to a master of science in computer science (M.S.C.S.), a master of science in electrical engineering (M.S.E.E.), and a master of science in software engineering (M.S.S.E.). It also participates in the Benjamin M. Statler College of Engineering and Mineral Resources interdisciplinary program offering the master 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. 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.

The department also offers graduate certificates in computer forensics and software engineering, 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 the Advanced Engineering Research Building along with resources in the Engineering Sciences Building and 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 (APERC). The Department and University are designated as a Center of Academic Excellence in Cyber Defense Education and 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. Students have access to a rich set of software packages and tool suites available either on department systems or the Benjamin M. Statler College of Engineering and Mineral Resources systems. 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

- Anurag Srivastava - Ph.D. (Illinois Institute of Technology)
  Power systems

PROFESSORS

- Donald Adjeroh - Ph.D. (Chinese University of Hong Kong)
  Associate Department Chair and Graduate Coordinator for Computer Science. Multimedia information systems (image, video, and audio), Distributed multimedia systems, Data analytics
- Muhammad Choudhry - Ph.D. (Purdue University)
  Associate Department Chair and Graduate Coordinator for Computer Engineering and Electrical Engineering. Power system control, DC transmission, Stability, Power electronics
- Parviz Famouri - Ph.D. (University of Kentucky)
  Associate Department Chair. 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
- Katerina Goseva-Popstojanova - Ph.D. (Ss. Cyril and Methodius University)
  Software engineering, Cybersecurity, Empirical studies, Data analytics
- 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
- Xin Li - Ph.D. (Princeton University)
  Image processing, Computer vision, Pattern recognition
- Nasser Nasrabadi - Ph.D. (Imperial College, London)
  Image and video processing, Biometrics, Video analytics
- Roy Nutter Jr. - P.E., Ph.D. (West Virginia University)
  Neural networks, Microprocessor systems, Computer architecture, Computer forensics
- Y.V. Ramana Reddy - Ph.D. (West Virginia University)
  Artificial intelligence, Knowledge-based simulation, Computer graphics
- Natalia Schmid - Ph.D. (Washington University)
  Detection and estimation, Statistical signal and image processing, Biometrics, Information theory, Wireless sensor networks, Signal processing for radio astronomy
- K. Subramani - Ph.D. (University of Maryland)
  Scheduling, Computational biology, Computational complexity, Polyhedral combinatorics
- Matthew Valenti - P.E., Ph.D. (Virginia Tech)
  Communication Theory, Wireless Networks, Error Control Coding
- Brian Woerner - Ph.D. (University of Michigan)
  Wireless communications, Networking, Cybersecurity

ASSOCIATE PROFESSORS

- Xian-An Cao - Ph.D. (University of Florida)
  Nanofabrication, Opto-electronic devices
- Jeremy Dawson - Ph.D. (WVU)
  Photonics, Nanofabrication, Biometrics data sensing and Rapid DNA analysis
• Gianfranco Doretto - Ph.D. (University of California - Los Angeles)
  Computer vision, Statistical pattern recognition, Biometrics, Image processing, Computer graphics
• Elaine Eschen - Ph.D. (Vanderbilt University)
  CCDM Program Director, Design and analysis of algorithms, Graph theory, Combinatorics
• David Graham - Ph.D. (Georgia Institute of Technology)
  Analog signal processing
• Sarika Khushalani-Solanki - Ph.D. (Mississippi State University)
  Power/energy conversion, Power systems, Controls, Signals and systems
• Yuxin Liu - Ph.D. (Louisiana Tech University)
  Biotechnology/bioengineering, BioMEMS and microfluidics, Cellular senor, Tissue engineering
• Daryl Reynolds - Ph.D. (Texas A&M)
  Statistical signal processing for communications, Iterative (turbo) processing, Transmitter pre-coding, Space-time coding and processing
• Frances VanScoy - Ph.D. (University of Virginia)
  Programming languages and compilers, Multisensory computing, High performance computing

TEACHING ASSOCIATE PROFESSORS
• Mohamed Hefeida - Ph.D. (University of Illinois-Chicago)
  Digital design, Computer architecture, Advanced communication systems, Cross-layer design and optimization

ASSISTANT PROFESSORS
• Amir Alipour-Fanid - Ph.D. (George Mason University)
  Cyberphysical systems, cybersecurity, internet of things
• Kevin Bandura - Ph.D. (Carnegie Mellon University)
  Radio astronomy, Digital signal processing, Antennas

TEACHING ASSISTANT PROFESSORS
• Tom Devine - Ph.D. (West Virginia University)
  Software engineering, Operating systems, Data science, Machine learning
• Brian Powell - Ph.D. (West Virginia University)
  Software engineering, Programming, Image processing
• Jignesh Solanki - Ph.D. (Mississippi State University)
  Power engineering, Smart grids, Decentralized control of power systems, Control and automation of distribution and transmission systems

RESEARCH ASSISTANT PROFESSORS
• Saiph Savage - Ph.D. (University of California - Santa Barbara)
  Machine learning, Human computer interaction, Data analytics for social networks

TEACHING INSTRUCTORS
• Camille Hayhurst - M.S. (West Virginia University)
• Ron Reaser - M.S. (West Virginia University)

RESEARCH ASSOCIATES
• Dale Dzielski - M.B.A., C.M.A., P.M.P. (Regent University)
  Director of Software Engineering Programs and Graduate Coordinator for Software Engineering, Software project management, Business process management/supply chain, Enterprise architecture, Architecture technical debt
• David Krovich - M.S. (West Virginia University)
  Cybersecurity, Networking, Operating systems, Open-source software
• Don McLaughlin - M.A. (West Virginia University)
  Artificial intelligence, High performance computing, Data science, Computer graphics

LECTURERS
• Kenneth Costello - M.S. (West Virginia University)
• Martin Dombrowski - M.S. (West Virginia University)
• Jeffrey Edgell - M.S. (Stephens Institute of Technology)
• Lawrence Jacowitz - Ph.D. (Ohio State University)
• Gregory Mundy - M.Sc. (West Virginia University)
• Cynthia Tanner - M.S. (West Virginia University)
• Scott Warden - M.S. (West Virginia University)

ADJUNCT PROFESSORS
• William Cawthorne - Ph.D. (West Virginia University)
  Electrified vehicles, Control systems, Software architecture, Engineering leadership
• Lawrence Hornak - Ph.D. (Rutgers University)
  Optics, Integrated Optics, Micro/Nano Structures and Devices, Biosensors, Biometrics
• Michael Yura - Ph.D. (Ohio State University)
  New and innovative biometric technology

ADJUNCT ASSOCIATE PROFESSORS
• Thirimachos Bourlai - Ph.D. (University of Surrey)
  Biomedical image processing, Pattern recognition
• Yu Gu - Ph.D. (West Virginia University)
  Robotics, Design, Automatic controls, Mechatronics
• Guodong Guo - Ph.D. (University of Madison-Wisconsin)
  Computer vision, Biometrics, Human computer interaction
• V. Jagannathan - Ph.D. (Vanderbilt University)
  Distributed intelligent systems, Internet and security technologies, Natural language processing
• V. Kulathumani - Ph.D. (Ohio State University)
  Wireless sensor actuator networks, Scalable and fault tolerant distributed systems
• Guilherme Pereira - Ph.D. (Federal University of Minas Gerais, Brazil)
  Sensor fusion, Multi-robot systems
• Sumitra Reddy - Ph.D. (West Virginia University)
  Healthcare Informatics, Componentware, Intelligent Systems, Information Technology Evolution
• Xueyan Sherry Xu - Ph.D. (West Virginia University)
  Biomedical signal processing, Pattern recognition, Human vibration evaluation and risk assessment
• Yanfang Ye - Ph.D. (Xiamen University)
  Computer security, Malware detection, Machine learning

ADJUNCT ASSISTANT PROFESSORS
• Omid Dehzangi - Ph.D. (Nanyang Technological University)
  Data structures, Expert and decision support systems, Big data, Data mining, Artificial intelligence
• Victor Fragoso - Ph.D. (University of California - Santa Barbara)
  Computer vision, Machine learning
• Bin Liu - Ph.D. (Rutgers University)
  Data mining, Machine learning

PROFESSORS EMERITI
• Hany Ammar - Ph.D. (University of Notre Dame)
• John Atkins - Ph.D. (University of Pittsburgh)
• Wils Cooley - Ph.D., P.E. (Carnegie Mellon University)
• Mark Jerabek - Ph.D., P.E. (Purdue University)
• Robert McConnell - Ph.D. (University of Kentucky)
• James Mooney - Ph.D. (Ohio State University)
• George Trapp - Ph.D. (Carnegie Mellon University)

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 591. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CPE 595. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

CPE 620. Deep Learning. 3 Hours.
PR: CPE 520. Review of neural network architectures; introduction to advanced deep neural network architectures that use many layers and large databases; application of deep learning to dimensionality reduction, latent feature extraction, and manifold representation; coupled deep neural networks for cross-modality object verification; use of multiple neural networks for data fusion; applications of deep learning in biometrics, computer vision, and data mining.

CPE 643. Fault Tolerant Computing. 3 Hours.

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 691. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CPE 693. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

CPE 694. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

CPE 695. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

CPE 697. Research. 1-9 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 791. 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 795. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

CPE 796. Graduate Seminar. 1-3 Hours.
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. 1-9 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper, or equivalent scholarly project, or a dissertation. (Grading may be S/U.).

**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 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 560. Big Data Engineering. 3 Hours.
PR: LCSEE graduate standing, or consent. Survey of the algorithms, methods, and technologies involved in building, organizing and analyzing massive datasets. Explores the field of data science from a computational perspective.

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.

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 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 591B-Q. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CS 592. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

CS 593. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

CS 594. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

CS 595. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

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 691X. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CS 692. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

CS 693. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

CS 695. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

CS 696. Graduate Seminar. 1-3 Hours.
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. 1-9 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 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 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 791X. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

CS 792. 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 795. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.
**CS 796. Graduate Seminar. 1-3 Hours.**
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. 1-9 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 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 provide 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.**

**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 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 446 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.**

**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 445 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 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 591L-V. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 593. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

EE 595. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

EE 613. Detection and Estimation Theory. 3 Hours.

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 668. Information Theory. 3 Hours.
PR: EE 513. Mathematical description of channels and sources; entropy, information, data compression, channel capacity, Shannon’s theorems, rate-distortion theory, maximum entropy principle, and large deviations theory.

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 691. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 692. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

EE 695. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

EE 697. Research. 1-9 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.
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.

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 791. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

EE 792. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

EE 793. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

EE 795. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

EE 796. Graduate Seminar. 1-3 Hours.
PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

EE 797. Research. 1-9 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U).

SOFTWARE ENGINEERING COURSES

SENG 505. Programming Applications with Java. 3 Hours.
PR: Consent. This course serves as an introduction to developing application software. It covers solving problems using the Java programming language. Topics include problem-solving, fundamentals of programming, basic algorithms and data structures, data organization, defensive programming, relational databases and creating database applications.

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. Software Verification and Validation. 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.

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 585. Software Engineering Economics. 3 Hours.
PR: SENG 510 or instructor consent. The software engineering economics fundamentals to real-world software economic problems addressed to include software life cycle economics and concepts of risk and uncertainty to software development projects. Application of best practices economic analysis methods for software life-cycle economics, including portfolio and product line management, investment decisions, and earned value management.
SENG 591. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

SENG 610. Strategies for Managing Software Projects. 3 Hours.

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 650. Cloud Computing for the Internet of Things. 3 Hours.
PR: SENG 550 or consent. Investigation of cloud computing techniques and architectures for the Internet of Things (IoT). Basic concepts and current practices of cloud computing and IoT. Topics include cloud computing models, technologies, security, and privacy. Exploration of example applications and patterns of IoT.

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 691. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

SENG 695. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

SENG 697. Research. 1-9 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/U).