

COMPUTER SCIENCE AND ENGINEERING (CSE)

CSE 511: Operating Systems Design

3 Credits

Concurrent programming; design of I/O subsystem, memory management, and user interface; kernel design; deadlocks, protection and security; case studies.

Prerequisite: CMPSC473

CSE 513: Distributed Systems

3 Credits

Protocol hierarchies; routing and flow control algorithms; distributed operating systems; communication and synchronization mechanisms; resource allocation problems.

Prerequisite: CSE 411

CSE 514: Computer Networks

3 Credits

Network subsystems, ARPANET, SNA, DECNET, network protocols (physical databank, network, transport, sessions, presentation, application), routing and congestion control, network optimization. CSE 514 CSE 514 Computer Networks (3) This course discusses the characteristics and low-level protocols of computer networks. It provides basic background, design, and evaluation skills in telecommunication and communication networks. The course will cover International Standards Organization Open System Interconnection (ISO-OSI) reference model, design issues and protocols in the data link layer, network layer and transport layer; architectures and control algorithms of local-area networks, and point-to-point networks; standards in network access protocols; models of network interconnection; and overview of networking and communication software. The course will emphasize on Internet standards such as TCP/IP and many advanced topics in networking. Students should already have some network background before taking this course. Students should also have necessary analytical and programming skills to do networking projects.

Prerequisite: CMPEN362 ; E E 353 or E E 350

CSE 515: Reliable Data Communications

3 Credits

Discussion of problems and solutions for ensuring reliable and efficient communication over wired and wireless links and data networks.

Prerequisite: Communication Networks; STAT 418
Cross-listed with: EE 565

CSE 516: Mobile Networking

3 Credits

Algorithms, systems and design of mobile telecommunication voice and data networks. CSE 516 Mobile Networking (3) This course presents the fundamentals of mobile networking and provides simple analytical tools for designing and evaluating these networks. The course is divided

into three parts. First, the architecture and algorithms for mobility management and service control in classic circuit-switched cellular networks is presented. Using simple queuing models, students analyze the performance of these networks and examine design trade-offs. GSM is used as a case study. Second, the architecture and algorithms for mobility management is packet-based mobile telecommunications networks are presented. Finally, protocols, algorithms, and performance consideration for the mobile Internet are presented. This course focuses on the practical applications of these concepts, using real systems to illustrate architecture and protocol trade-offs. The course provides students with a venue in which to pursue research in mobile networking that complements several core areas of the graduate CSE curriculum (e.g., networks, architectures, algorithms, and formal analysis). Following the course in networking, this course enables students to learn the skills and obtain the background knowledge necessary to generate publishable research in the area of mobile networks. This course will serve as an elective for students interested in mobile networking and telecommunications.

CSE 517: Performance Evaluation

3 Credits

Tools and techniques for PE, Analytical and Simulation models, evaluation of multiprocessors, multicomputer and LANs, scheduling policies, case studies.

CSE 521: Compiler Construction

3 Credits

Design and implementation of compilers.

CSE 522: Program Analysis

3 Credits

This course explores the fundamental concepts, algorithms, and engineering processes of analyzing programs for correctness, security, and performance. It is intended as a course for first-year or second-year graduate students in computational majors such as computer science and computer engineering since it covers how to analyze programs rigorously based on program semantics. First, the course will cover basic static analysis algorithms, from dataflow analysis to complex points-to analysis. This part will also cover logical programming and ask students to implement static-analysis algorithms using logical programming. The next part will give an overview of the theory of static analysis, using the framework of abstract interpretation. The third part will focus on dynamic analysis and its instances such as taint tracking. The final part will discuss one application of static analysis in analyzing binary code for security. Upon successful completion of the course students will be able to demonstrate understanding of and implement the basic program analysis algorithms and be able to customize these algorithms for specific applications.

Prerequisites: CMPSC 461 or CMPSC 464

CSE 523: Programming Languages

3 Credits

This course explores advanced concepts of programming languages and how the concepts are applied to language-based security. The course first covers programming language theory, including program semantics, Induction, lambda calculus. Then, the course covers language-

based techniques, such as type system and program verification, that can provably rule out incorrect/insecure programs. Finally, the course engages the students with hands-on projects to apply the techniques to solve security problems, such as analyzing information flow leakage in programs and automatic code rewriting to avoid side channel attacks. Upon completion of the course, students will demonstrate understanding of advanced programming language concepts and be ready to apply them for specific applications.

CSE 530: Fundamentals of Computer Architecture

3 Credits

Advances in computer architecture, Pipelining, parallelism, and multiprocessing.

Prerequisite: CMPEN431

CSE 531: Parallel Processors and Processing

3 Credits

Parallel processor organization; basic algorithms suitable for such systems; parallel sorting and interconnection networks; applications and discussion of specific processors.

Prerequisite: CSE 530

CSE 532: Multiprocessor Architecture

3 Credits

Fundamental structures of multiprocessors; interprocess communications, system deadlocks and protection, scheduling strategies, and parallel algorithms; example multiprocessor systems.

Prerequisite: CSE 530

CSE 536: Fault Tolerant Systems

3 Credits

Attributes of fault-tolerant systems and their definitions; reliability and availability techniques; maintainability and testing techniques; practice of reliable system design.

Prerequisite: CSE 530

CSE 539: Topics in Computer Architecture

3 Credits

Study of current advanced issues in design, implementation and applications of complex computer systems.

Prerequisite: CSE 530

CSE 541: Database Systems I

3 Credits

Data models and relational database design; database integrity and concurrency control; distributed database design and concurrency control; query optimization.

Prerequisite: CMPSC431W

CSE 543: Computer Security

3 Credits

Specification and design of secure systems; security models, architectural issues, verification and validation, and applications in secure database management systems.

Prerequisite: CMPSC461

CSE 544: System Security

3 Credits

Review current research in computer and operating system security. CSE 544 System Security (3) This course is built around the problem of authorization (access control). After a discussion of threats of systems security, we will examine the fundamental mechanism for access control, the reference monitor. We will define the principle of the reference monitor and review how it is used to implement access control. The second major topic is mandatory access control (MAC). We will examine the implementation of MAC in Linux via the Linux Security Modules (LSM) framework. This part of the class relies heavily on a case study of the SELinux system to illustrate how MAC can be implemented and how security goals can be enforced by using MAC. The third major topic focuses on how network security functions are implemented in the operating system. Such functions include authentication, firewalls, and secure communication via IPsec. The implementations of such functions in the Linux operating system will be the focus of this particular section of the course. The third major topic examines system security architectures for distributed systems. The main foci are mechanisms based on public key systems, such as trust management, integrity measurement, and web-based operating systems. We will investigate research results in these areas and hypothesize where this emerging space may evolve. The fourth major topic focuses on lower level features of operating systems and their impact on security. We will first review virtual machine systems and recent research results that indicate an emergence of virtual machine mechanisms as a practical basis for achieving strong systems security guarantees. We will then explore work on protecting access to data on systems that is resident in traditional (file systems) and unexpected (other temporary) storage locations. The final two sections, Special Topics and Wrap-Up, will cover a number of areas of importance to system security, but not really falling into the traditional system areas. This includes emerging topics such as language-based security, the use of source code analysis for achieving system security goals, host intrusion detection, and emerging areas of recent interest. These topics will change over time as interests and technology develop. We will conclude with a discussion of the major challenges and state of system security, and make predictions about the future of system security.

Prerequisite: CSE 458 , CSE 411 , CSE 543

CSE 545: Network Security

3 Credits

Advanced methods and technologies for network security. CSE 545 Network Security (3) CSE 545 covers the major topics and emerging trends in network security. We begin with a discussion of the basic problems, architectures and devices in current and next generation networks. This will include a discussion of how these topics relate to popular articles and the press. This part of the class relies heavily on case studies to illustrate how security impacts the social and technical

aspects of the Internet and computing systems. The second major topic focuses on the use of applied cryptography supporting network protocols. This will provide a deeper view of the basics of cryptographic constructions and consider formal methods for proving their correctness. The realities and limitations of the current use of cryptography will be considered. Students will spend a considerable amount of time developing and analyzing their own security protocols. The third section of this course will focus on the management and vulnerabilities of current network environments. This will begin with a discussion of emerging authentication systems (federated authentication, graphical passwords, biometrics), and then turn to the security problems of large-scale network management. The class will then review major thrusts in network security: the management and vulnerabilities of wireless systems. The course concludes with a discussion of topical areas in network security. This is the most flexible part of the class, and will reflect the needs and desires of the instructors and students on a semester-to-semester basis.

Prerequisite: CSE 543

CSE 546: Cryptography

3 Credits

Introduction to the theory and techniques of modern cryptography, with emphasis on rigorous analysis and mathematical foundations. CSE 546 Cryptography (3) This course provides an introduction to the theory and techniques of modern cryptography. The course begins by reviewing relevant mathematical tools and moves on to develop definitions and examples of secure protocols for important cryptographic tasks such as symmetric- and private-key encryption, authentication, and digital signatures. Students will be evaluated primarily on weekly problem sets designed to verify and improve their understanding of the materials. Grades will be based on problem sets, a mid-semester examination, a final examination, and class participation/lecture notes. With regard to "lecture notes," students (in teams) must prepare a written summary of one lecture during the course. The goal of this exercise is to practice technical writing and exposition. This course will serve as an elective for graduate students in Computer Science & Engineering and the Post-Baccalaureate Credit Certificate Program in Computer & Network Security (under development).

Prerequisite: CSE 465

CSE 547: Wireless and Mobile Security

3 Credits

While wireless communications and mobile applications have made our daily life much easier, they also bring to us various security and privacy threats that did not exist in the wired networks. This course explores the latest research literature in security and privacy of emergent wireless and mobile systems including sensor networks, smartphones, cellular networks, Internet of Things (IoT), drones, autonomous driving, and wearable devices. Students will learn the theoretical framework, analytical skills and research methodology and tools in the this field, and synthesize their knowledge to formulate security models, design security protocols, apply principled security analysis techniques for network and software flaws, and malware detection, evaluate the security and privacy threats of various mobile systems as well as the challenges and design solutions for addressing them. Research papers on these topics in recent computer-science conferences and journals will be included for reading and discussion.

Prerequisite: CMPSC 443 or CSE 543

CSE 550: Numerical Linear Algebra

3 Credits

Solution of linear systems, sparse matrix techniques, linear least squares, singular value decomposition, numerical computation of eigenvalues and eigenvectors.

Prerequisite: MATH 441 or MATH 456

Cross-listed with: MATH 550

CSE 551: Numerical Solution of Ordinary Differential Equations

3 Credits

Methods for initial value and boundary value problems; convergence and stability analysis, automatic error control, stiff systems, boundary value problems.

Prerequisite: MATH 451 or MATH 456

Cross-listed with: MATH 551

CSE 552: Numerical Solution Of Partial Differential Equations

3 Credits

Finite difference methods for elliptic, parabolic, and hyperbolic differential equations; solutions techniques for discretized systems; finite element methods for elliptic problems.

Prerequisite: MATH 402 or MATH 404 ; MATH 451 or MATH 456

Cross-listed with: MATH 552

CSE 554: Error Correcting Codes for Computers and Communication

3 Credits

Block, cyclic, and convolutional codes. Circuits and algorithms for decoding. Application to reliable communication and fault-tolerant computing.

Prerequisite: Communication Networks

Cross-listed with: EE 564

CSE 555: Numerical Optimization Techniques

3 Credits

Unconstrained and constrained optimization methods, linear and quadratic programming, software issues, ellipsoid and Karmarkar's algorithm, global optimization, parallelism in optimization.

Prerequisite: CMPSC456

Cross-listed with: MATH 555

CSE 556: Finite Element Methods

3 Credits

Sobolev spaces, variational formulations of boundary value problems; piecewise polynomial approximation theory, convergence and stability, special methods and applications.

Prerequisite: MATH 502 , MATH 552

Cross-listed with: MATH 556

CSE 557: Concurrent Matrix Computation

3 Credits

This course discusses matrix computations on architectures that exploit concurrency. It will draw upon recent research in the field.

Prerequisite: CMPSC451 , CMPSC455 , CMPSC450 , MATH 451 , or MATH 455

CSE 559: Wireless and Mobile Sensing in the Age of IoT

3 Credits

This course covers state-of-the-art research on Internet of Things (IoT), with a focus on wireless networking and mobile sensing. Topics of discussion include high precision localization, GPS, smart healthcare, autonomous vehicles and drones, Augmented/Virtual Reality, Battery free communication, 5G basics, Security etc. The course begins with a basic background in linear algebra, signal processing, wireless communications in the context of applications. Thereafter, the topics will be organized into various applications and research from top notch conferences will be presented. In addition, within each application, the appropriate background and common principles underlying Bayesian Filtering, Maximum Likelihood, Sensor design basics etc will be emphasized.

Recommended Preparations: Programming skills are required. Ability to program in any programming language is fine.

CSE 561: Data Mining Driven Design

3 Credits

The study and application of data mining/machine learning (DM/ML) techniques in multidisciplinary design. CSE 561 / EDSGN 561 / IE 561 / IST 561 Data Mining Driven Design (3) This course examines how theoretical data mining/machine learning (DM/ML) algorithms can be employed to solve large-scale, complex design problems. Knowledge Discovery in Databases (KDD) is the umbrella term used to describe the sequential steps involved in capturing and discovering hidden, previously unknown knowledge in large databases. The course begins with foundational information regarding engineering design and provides an overview of KDD and the emergence of the digital age. Students will investigate data acquisition and storage techniques where they will learn the difference between stated and revealed data as related to design. Students will construct their own databases and learn essential techniques in data base queries (SQL) and management. Data transformation techniques, such as binning and dimensionality reduction, will be examined in the data transformation section of the course. This course has a design-driven focus, which will enable students to solve real-life design challenges spanning diverse domains. Students will work on project-based exercises aimed at proposing novel data mining algorithms, or employing existing algorithms to solve design problems in fields relating to engineering, healthcare, financial markets, military systems, to name a few. Data visualization techniques will also be studied to help communicate complex data mining models in a timely and efficient manner.

Cross-listed with: EDSGN 561, IE 561, IST 561

CSE 562: Probabilistic Algorithms

3 Credits

Design and analysis of probabilistic algorithms, reliability problems, probabilistic complexity classes, lower bounds.

Prerequisite: CSE 565

CSE 564: Complexity of Combinatorial Problems

3 Credits

NP-completeness theory; approximation and heuristic techniques; discrete scheduling; additional complexity classes.

Prerequisite: CSE 565

CSE 565: Algorithm Design and Analysis

3 Credits

An introduction to algorithmic design and analysis.

Prerequisite: CMPSC465; Concurrent: CMPSC464

CSE 566: Algorithms and Data Structures in Bioinformatics

3 Credits

This course covers elegant algorithmic and data structure techniques that underpin modern biological data analysis. Bioinformatics is a growing field with immediate implications for our understanding of biology and treatment of disease. This course covers elegant algorithmic and data structure techniques and their use in bioinformatics. The emphasis is on recurrent ideas that underpin modern biological data analysis, presented in conjunction with their biological applications. The course is suitable both for students interested in doing bioinformatics research and those interested in applications of algorithms to the natural sciences. Some of the algorithms/data-structures that may be covered include exact string matching, suffix trees, suffix arrays, de Bruijn graphs, hidden Markov models, breakpoint graphs, succinct data structures, the Burrows-Wheeler transform, the FM-index, network flow, and bidirected graphs. Some of the biological applications will include sequence alignment and assembly, cancer genomics, phylogeny, gene finding, and variation detection. No prior biological or bioinformatics knowledge is required. A basic understanding of data structures and algorithms (equivalent to CMPSC465) is a prerequisite; however, exceptionally motivated students can contact the instructor to discuss their options. This course is complementary to existing bioinformatics courses offered through other programs on campus. These courses may be taken concurrently but are not prerequisites. Prerequisites: CMPSC465 Cross Listings: BMMB 566 will be added as a cross-listed course.

Prerequisite: CMPSC465

Cross-listed with: BMMB 566

CSE 575: Architecture of Arithmetic Processors

3 Credits

Algorithms and techniques for designing arithmetic processors; conventional algorithms and processor design; high-speed algorithms and resulting architectural structures.

Prerequisite: CMPEN411

CSE 577: VLSI Systems Design

3 Credits

Engineering design of large-scale integrated circuits, systems, and applications; study of advanced design techniques, architectures, and CAD methodologies.

Prerequisite: CMPEN411

CSE 578: VLSI Computer-Aided Design Tools

3 Credits

VLSI circuit design tools: placement, routing, extraction, design rule checking, graphic editors, simulation, verification, minimization, silicon compilation, test pattern generation.

Prerequisite: CMPEN411

CSE 582: Natural Language Processing

3 Credits

The question addressed by the field of natural language processing (NLP), or computational linguistics, is how to get computers to process human language in a useful manner, such as to extract information from text, to generate text from semantic representations, or to support human-machine interaction through language. This overview course presents natural language processing in two ways. From one perspective, it is an applied computational discipline, where the main goal is to turn language data into computable data. This makes it possible to build many applications where human language is processed, and to invent new applications. NLP is also a theoretical discipline that addresses problems in how to identify the units and structures of language, such as how to specify the vocabulary of a language, how to describe the allowable combinations of words, how to represent the meanings of words and phrases, and how to get at the implicit intentions of language users. The class covers both aspects of NLP.

CSE 583: Pattern Recognition and Machine Learning

3 Credits

This course is a comprehensive overview of the fields of pattern recognition and machine learning. The content covers both classification and recursion, model selection, decision theory, information theory, linear and non-linear models, graphical models, kernel methods, mixture models and EM as well as neural networks. It assumes no previous knowledge of pattern recognition or machine learning concepts. Knowledge of multivariate calculus and basic linear algebra is required, and some familiarity with probability would be helpful.

Recommended Preparations: Multivariate calculus, linear algebra, probability
Cross-listed with: EE 552

CSE 584: Machine Learning: Tools and Algorithms

3 Credits

Computational methods for modern machine learning models, including applications to big data and non-differentiable objective functions.

Cross-listed with: STAT 584

CSE 585: Digital Image Processing II

3 Credits

Advanced treatment of image processing techniques; image restoration, image segmentation, texture, and mathematical morphology.

Prerequisite: CMPEN455 or E E 455
Cross-listed with: EE 555

CSE 586: Topics in Computer Vision

3 Credits

Discussion of recent advances and current research trends in computer vision theory, algorithms, and their applications.

Prerequisite: CMPEN454 or E E 454
Cross-listed with: EE 554

CSE 587: Deep Learning for Natural Language Processing

3 Credits

Natural Language Processing (NLP) is a critical part of Artificial Intelligence and Data Science. Over the past few years, deep learning based on neural networks has become the de facto approach for a wide range of NLP tasks. In this course, we will start with foundations of deep learning including multi-layer perceptrons, backpropagation, and specialized types of neural networks for different forms of data. The second part focuses on cutting-edge NLP progress. We will start with fundamental natural language understanding tasks, then cover text generation models, and progress to applications spanning different modalities and languages. We will also discuss methods for explainability, interpretability, bias and fairness, and efficiency.

Prerequisites: CMPSC 448 CSE 582

CSE 588: Large-Scale Machine Learning: Mathematical Foundations and Applications

3 Credits

This course covers various mathematical aspects of big and high-dimensional learning arising in data science and machine learning applications. The focus will be on building a principled understanding of randomized methods via a mixture of empirical evaluations and mathematical modeling. Specifically, we will explore large-scale optimization algorithms for both convex and non-convex optimization, dimension reduction and random projection methods, large-scale numerical linear algebra, sparse recovery and compressed sensing, low-rank matrix recovery, convex geometry and linear inverse problems, empirical processes and generalization bounds, as well as theory and optimization landscape of neural networks, etc. The course material builds upon the basic principles of machine learning, using multivariate calculus, linear algebra, basic probability, and algorithms. Emphasis will be on producing mathematical arguments and rigorous proofs.

Prerequisite: CMPSC 448

CSE 590: Colloquium

1-3 Credits/Maximum of 3

Continuing seminars which consist of a series of individual lectures by faculty, students, or outside speakers.

CSE 591: Research Experience in Computer Science and Engineering

1 Credits

Research experience for new doctoral students in computer science and engineering. Research is performed in conjunction with another 500-level CSE course.

Concurrent: enrollment in another 500-level CSE course

CSE 594: Research Topics

1-15 Credits/Maximum of 15

Supervised student activities on research projects identified on an individual or small-group basis.

CSE 596: Individual Studies

1-9 Credits/Maximum of 9

Creative projects, including nonthesis research, which are supervised on an individual basis and which fall outside the scope of formal courses.

CSE 597: Special Topics

1-9 Credits/Maximum of 9

Formal courses given on a topical or special interest subject which may be offered infrequently; several different topics may be taught in one year or term.

CSE 598: Special Topics

1-9 Credits/Maximum of 9

Formal courses given on a topical or special interest subject which may be offered infrequently; several different topics may be taught in one year or semester.

CSE 600: Thesis Research

1-15 Credits/Maximum of 999

No description.

CSE 601: Ph.d. Dissertation Full-Time

0 Credits/Maximum of 999

No description.

CSE 602: Supervised Experience in College Teaching

1-3 Credits/Maximum of 3

Supervised experience in teaching and orientation to other selected aspects of the profession at The Pennsylvania State University.

CSE 610: Thesis Research Off-Campus

1-15 Credits/Maximum of 999

No description.

CSE 820: Software & Hardware Project Management

3 Credits

Students study the theory and practice of hardware and software project management. CSE 820 Software & Hardware Project Management (3) This course provides a broad exploration of the field of software, hardware, and integrated software/hardware project management. In particular, it investigates the fundamentals of risk, scope, time and cost management, quality assurance, scheduling, and human resource functions. It considers the nuances of software, hardware, and integrated hardware/software project management, as distinct from the management of projects in, say, building construction or manufacturing. Building on these insights, the student will learn how to apply these techniques to a real-world project of his or her choosing. Students will learn to recognize, identify, and apply the functions of project management to the types of projects which they will encounter in industry. This course supports the professional nature of the MEng degree.