COMPUTER AND INFORMATION SCIENCE AND ENGINEERING

CAI 5731 Biostatistics for AI 2 Credits
Grading Scheme: Letter Grade
Biostatistics for AI highlights the crucial role of biostatistics in AI-driven medical applications. Students will master foundational biostatistical methods, design effective medical experiments, and navigate the intricacies of large biomedical datasets. Emphasizing the union of traditional biostatistics with contemporary AI techniques, the course ensures proficiency in data analysis, AI model validation, and addressing ethical challenges in medical data use.
Prerequisite: Prior coding experience is helpful but not mandatory.
Corequisite: Recommended but not mandatory: CAI 5720 and CAI 5724 both with a minimum grade of C.

CAI 5732 AI for Clinical Decision Support 3 Credits
Grading Scheme: Letter Grade
Explores the current landscape of clinical artificial intelligence (AI) for augmenting patient care, including real-world deployments, promising cutting-edge research, and ethical and societal implications of current clinical AI progress. A hybrid flipped classroom/journal club structure which emphasizes peer engagement will empower students to join the ongoing conversation and become versed in the contemporary clinical AI topics that are currently shaping the field.

CAI 6108 Machine Learning Engineering 3 Credits
Grading Scheme: Letter Grade
Covers foundational machine learning concepts with an emphasis on applying these concepts on real-world data through programming exercises and assignments using the relevant industry-standard Python tools, libraries, and frameworks.
Prerequisite: Knowledge of programming fundamentals. Experience with Python is a plus but not required.

CAI 6307 Natural Language Processing 3 Credits
Grading Scheme: Letter Grade
Covers concepts in natural language processing ranging from shallow bag-of words to richer representations and formalisms, for applications such as translation, generation, extraction, summarization, and dialogue. Classic and state-of-the-art techniques and remaining challenges are discussed, as well as recent proposals for meeting those challenges (both symbolic and machine learning approaches). Intended for graduate students doing research related to natural language processing.
Prerequisite: Proficiency in programming (Python recommended) & familiarity with introductory machine learning or artificial intelligence is a plus.

CAI 6726 Clinical AI Design Studio I 3 Credits
Grading Scheme: Letter Grade
Offers an immersive learning experience for students interested in the intersection of artificial intelligence (AI) and clinical practice. Throughout the semester, students will participate in rotations, spending time working in various faculty members' labs or clinical domains. These rotations provide a unique opportunity to delve into various research domains and acquire valuable insights into ongoing clinical AI initiatives.
Prerequisite: (CAI 5720 and CAI 5721 and CAI 5724 and CAI 6725) all with a minimum grade of C.

CAI 6727 Clinical AI Design Studio II 3 Credits
Grading Scheme: Letter Grade
Clinical AI Design Studio II offers a unique, extended engagement with a faculty advisor, building upon the foundational experiences from Clinical AI Design Studio I. Students will delve into the specialized clinical domain of their advisor, gaining firsthand insights into the intricacies of patient care and medical decision-making processes.
Prerequisite: (CAI 5720 and CAI 5721 and CAI 5724 and CAI 5723 and CAI 6725 and CAI 6726) all with a minimum grade of C.

CAI 6826 Project in Artificial Intelligence Systems 3 Credits
Grading Scheme: Letter Grade
Using concepts learned in prerequisite courses, including AI ethics, machine learning, and the Artificial Intelligence Systems course, students will individually or as a team identify AI systems problems, formulate solutions, and apply AI Systems knowledge in the context of a real-world project. Project requirements include preparing a plan, technical final report, delivering an oral presentation, and creating a software repository.
Prerequisite: (LAW 6930 & EGN 5216) AND (CAP 6615 or EGN 6615) AND (CAP 5416 or EEE 6512 or EEL 5406) AND (CAP 6XXX or EEE 6561 or EEL 5793).

CAI 6910 Supervised Research in AI for Health 1-5 Credits, Max 5 Credits
Grading Scheme: Letter Grade
Students will work with their technical and clinical advisors to design, develop, and complete an agreed-upon project, the substantiveness of the project to be determined by number of credit hours the student enrolls in. Students may take this course to advance their research interests by working in an advisor's lab or clinic, completing a reading course, or completing a capstone project or a Master's Thesis.
Prerequisite: CAI 6726 and CAI 6727 both with a minimum grade of C.

CAP 5100 Human-Computer Interaction 3 Credits
Grading Scheme: Letter Grade
Topics related to interaction with technology, including interface design, software tools, 3-D interaction, virtual environments, interaction devices, collaboration, and visualization.
Prerequisite: COP 3530, and any one programming course (COP 2800, COP 3275, or COP 3229).

CAP 5108 Research Methods for Human-Centered Computing 3 Credits
Grading Scheme: Letter Grade
Introduces the fundamental methods and techniques to evaluate technologies and collect data from humans, including experimental design, types of variables, types of errors, hypothesis testing, survey design, behavioral and psychophysical methods.
Prerequisite: STA 3032, COT 3100, COP 3530, or equivalent.

CAP 5404 Deep Learning for Computer Graphics 3 Credits, Max 6 Credits
Grading Scheme: Letter Grade
Covers fundamental theory and application of popular artificial intelligence (AI) algorithms in computer graphics. Introduces several neural network architectures and the mathematical principles behind them. A semester-long project motivated by research publications teaches technical writing and graphics processing unit (GPU) programming on a GPU cluster. Convolutional neural networks for denoising movies and generative adversarial networks for animation are project examples.
Prerequisite: Proficiency in a programming Language (Python and/or C ++ recommended), Data Structures and Algorithms, Linear Algebra, and Calculus.CAP5404

CAP 5416 Computer Vision 3 Credits
Grading Scheme: Letter Grade
Introduction to image formation and analysis. Monocular imaging system projections, camera model calibration, and binocular imaging. Low-level vision techniques, segmentation and representation techniques, and high-level vision.
Prerequisite: PrerequisitesMAC 2312 or equivalent, COT 4501 or equivalent and Proficiency in MATLAB or C++ or Java. Course instructor will determine equivalency.

CAP 5510 Bioinformatics 3 Credits
Grading Scheme: Letter Grade
Basic concepts of molecular biology and computer science. Sequence comparison and assembly, physical mapping of DNA, phylogenetic trees, genome rearrangements, gene identification, biomolecular cryptology, and molecular structure prediction.
Prerequisite: CIS 3020 or equivalent.

CAP 5705 Computer Graphics 3 Credits
Grading Scheme: Letter Grade
Display device characteristics; system considerations, display algorithms. Curve and surface generation. Lighting models and image rendering.
Prerequisite: COP 3530.

CAP 5771 Introduction to Data Science 3 Credits
Grading Scheme: Letter Grade
Introducing the basics of data science including programming for data analytics, file management, relational databases, classification, clustering and regression. The foundation is laid for big data applications ranging from social networks to medical and business informatics.
Prerequisite: COP 3530 Data Structures and Algorithms or equivalent.

CAP 5841 Modeling and Computing with Geometry 3 Credits
Grading Scheme: Letter Grade
Introduction to modeling and shaping curved smooth geometry and computing on the geometry. Topics include curves, surfaces and volumetric representations. The course leverages numerical computing techniques and 3D computer graphics programming. The course combines lecture and seminar elements: towards the end of the course, students give presentations of classic (or by mutual consent recent) literature on Modeling and Computing with Geometry.
Prerequisite: Calculus in several variables, Programming in Matlab or OpenGL.

CAP 6137 Malware Reverse Engineering 3 Credits
Grading Scheme: Letter Grade
Introducing the theory and practice of software reverse engineering applied to analysis of malicious software (malware). Students learn techniques of static and dynamic analysis to help identify the behavior of programs presented without documentation or source code and to identify possible remediation and avoidance techniques.
Prerequisite: Computer Organization or Computer Architecture or Assembly Language Programming.
Corequisite: Operating Systems Principles.

CAP 6516 Medical Image Analysis 3 Credits
Grading Scheme: Letter Grade
Image formation, reconstruction mathematics (Fourier slice theorem, Abel, Hankel and Radon transforms), PDE-based denoising and segmentation, multidimensional clustering algorithms, iso-surface extraction, basic differential geometry of curves and surfaces, multidimensional splines, active 2D/3D models, image matching/registration with application to multimodal co-registration.
Prerequisite: expertise in image proc./comp. vision, proficiency in C language or MATLAB.

CAP 6610 Machine Learning 3 Credits
Grading Scheme: Letter Grade
Concepts in developing computer programs that learn and improve with experience. Emphasis on methods based on probability, statistics, and optimization.
Prerequisite: Mathematics for Intelligent Systems.

CAP 6615 Neural Networks for Computing 3 Credits
Grading Scheme: Letter Grade
Neural network models and algorithms. Adaptive behavior, associative learning, competitive dynamics and biological mechanisms. Applications include computer vision, cognitive information processing, control, and signal analysis.
Prerequisite: CAP 5635.

CAP 6617 Advanced Machine Learning 3 Credits
Grading Scheme: Letter Grade
Advanced concepts in developing computer programs that learn and improve with experience. Emphasis on methods based on probability, statistics, and optimization.
Prerequisite: CAP 6610.

CAP 6701 Advanced Computer Graphics 3 Credits
Grading Scheme: Letter Grade
Curved surface representations, representation and visualization of higher-dimensional fields, advanced rendering, collision detection and collision response, and scene navigation in context of high-level graphics environments.
Prerequisite: CAP 4730 or CAP 5705 or consent of instructor.

CAP 6769 Advanced Topics in Data Science 3 Credits
Grading Scheme: Letter Grade
Advanced topics in data science such as relational databases and parallel and distributed processing in the cloud, tree-based classifiers and support vector machines, dimensionality reduction and theories of visualization.
Prerequisite: Graduate standing, CAP 5771

CAP 6779 Projects in Data Science 3 Credits
Grading Scheme: Letter Grade
Advanced topics in data science, individual projects in application areas such as vision, natural language processing, computational fluid dynamics, social networks, bioinformatics, etc.
Prerequisite: Graduate standing and CAP 5571.

CDA 5155 Computer Architecture Principles 3 Credits
Grading Scheme: Letter Grade
Fundamental design issues of processor and computer architecture, a variety of design approaches for CPU, memory, and system structure.
Prerequisite: CDA 3101, COP 3530, and COP 4600.

CDA 5636 Embedded Systems 3 Credits
Grading Scheme: Letter Grade
Design of efficient and trustworthy embedded and cyber-physical systems consisting of hardware, software, firmware, sensors and actuators. It covers fundamental issues related to modeling and specification, design space exploration, hardware-software partitioning, synthesis and compilation, real-time operating systems, and application-specific optimizations targeting area, power, performance, temperature, energy, and security.
Prerequisite: Computer Organization.

CDA 6325C Cyber-physical System Security 3 Credits
Grading Scheme: Letter Grade
Covers foundational concepts of cyber-physical system security. In particular, hardware and software threats and mitigation strategies of integrating sensing and actuation, AI computation, infrastructure control, and networking. Students will analyze research papers, write technical essays, present security research problems, conduct hands-on testing, and learn the challenges of building secure systems.
Prerequisite: Basic proficiency with programming is required (e.g., Python, C++).

CEN 5035 Software Engineering 3 Credits
Grading Scheme: Letter Grade
Topics in projects organization, specification techniques, reliability measurement, documentation.
Prerequisite: COP 3504 and COT 3100.

CEN 5726 Natural User Interaction 3 Credits
Grading Scheme: Letter Grade
Introducing design, development, and evaluation of Natural User Interaction (NUI) technologies (e.g., non-keyboard and mouse technologies, such as touchscreen interaction, gesture interaction, speech interaction, etc.). Key concepts include hardware-to-software NUI pipeline and considerations in NUI software development (including existing platforms, toolkits, and APIs used to create NUI software).
Prerequisite: COP 3530(C)

CEN 5728 User Experience Design 3 Credits
Grading Scheme: Letter Grade
Introduces methods and tools used in User Experience Design (UXD): the early stages of software design focused on meeting user needs. Key concepts include user research, contextual design, design thinking, ideation, iterative design, prototyping, and design documentation. Software tools used in industry are used in class projects.
Prerequisite: COP 3530 or equivalent.

CEN 5735 Human-Centered Input Recognition Algorithms 3 Credits
Grading Scheme: Letter Grade
Human-centered methods for the design and evaluation of intelligent algorithms for recognizing user input in advanced modalities such as gesture, handwriting, speech, and more. Algorithms and modalities vary; students will implement and extend an existing algorithm, evaluating it on user input data students will collect from real people.

CEN 6070 Software Testing and Verification 3 Credits
Grading Scheme: Letter Grade
Concepts, principles, and methods for software testing and verification. Topics include human and machine-based testing strategies, formal proofs of correctness, and software reliability.
Prerequisite: CEN 5035.

CEN 6075 Software Specification 3 Credits
Grading Scheme: Letter Grade
Concepts, principles, and methods for practical specification. System modeling, requirements exploration, validation and prototyping, and documentation techniques.
Prerequisite: CEN 5035.

CIS 5209 Penetration Testing -- Ethical Hacking 3 Credits
Grading Scheme: Letter Grade
Introduction to the principles and techniques associated with the cybersecurity practice known as penetration testing or ethical hacking. The course covers planning, reconnaissance, scanning, exploitation, post-exploitation, and result reporting. The student discovers how system vulnerabilities can be exploited and learns to avoid such problems.
Prerequisite: COP 3530.

CIS 5370 Computer and Information Security 3 Credits
Grading Scheme: Letter Grade
Covers systematic threat and risk assessment; programmed threats and controls in hardware, software, and human procedures; security policies, models, and mechanisms; theoretical limitations and practical implementations; certification and accreditation standards; and case study reviews. Coursework includes a significant term project.
Prerequisite: COP 4600 Operating Systems or equivalent

CIS 5371 Introduction to Cryptology 3 Credits
Grading Scheme: Letter Grade
Introducing classical and modern cryptography and cryptanalysis, including symmetric and asymmetric (public key) ciphers. It covers cryptographic hash functions, block and stream ciphers, as well as differential and linear cryptanalysis. It reviews BAN logic, applications of cryptography, cryptographic standards and protocols, and analyzes case studies of failed implementations.
Prerequisite: COT 3100 Applications of Discrete Structures or equivalent ;
Corequisite: COT 5405 Analysis of Algorithms or equivalent

CIS 6261 Trustworthy Machine Learning 3 Credits
Grading Scheme: Letter Grade
Explores research at the intersection of machine learning and security and privacy. Topics include: adversarial machine learning; differential privacy; membership inference; fairness transparency; explainable/interpretable machine learning; deepfakes and disinformation.
Prerequisite: Knowledge of programming fundamentals, familiarity with machine learning and Python is a plus.

CIS 6307 Internet Data Streaming 3 Credits
Grading Scheme: Letter Grade
Fundamental concepts, data structures and algorithms about extracting information from packet streams on the Internet in real time, with applications in network security, traffic engineering, e-commerce, and big data analytics
Prerequisite: Data Structures and Algorithms.

CIS 6905 Individual Study 1-3 Credits, Max 6 Credits
Grading Scheme: Letter Grade
Individual Study
Prerequisite: consent of faculty member supervising the study.

CIS 6910 Supervised Research 1-5 Credits, Max 5 Credits
Grading Scheme: S/U
Supervised Research
Prerequisite: graduate status in CIS.

CIS 6930 Special Topics in CIS 3 Credits, Max 9 Credits
Grading Scheme: Letter Grade
Special Topics in CIS
Prerequisite: vary depending on topics.

CIS 6935 Graduate Seminar 1-12 Credits, Max 12 Credits
Grading Scheme: S/U
Presentations by visiting researchers, faculty members, and graduate students.

CIS 6940 Supervised Teaching 3 Credits, Max 5 Credits
Grading Scheme: S/U
A supervised teaching experience.

CIS 6971 Research for Master's Thesis 1-15 Credits
Grading Scheme: S/U
Research for Master's Thesis

CIS 7979 Advanced Research 1-12 Credits
Grading Scheme: S/U
Research for doctoral students before admission to candidacy. Designed for students with a master's degree in the field of study or for students who have been accepted for a doctoral program. Not appropriate for students who have been admitted to candidacy.

CIS 7980 Research for Doctoral Dissertation 1-15 Credits
Grading Scheme: S/U
Research for Doctoral Dissertation

CNT 5106C Computer Networks 3 Credits
Grading Scheme: Letter Grade
Design, implementation, and internals of networks. Routing, congestion control, internetworking, TCP/IP, optimization, and proxy services.

CNT 5410 Computer and Network Security 3 Credits
Grading Scheme: Letter Grade
Issues, analysis, and solutions. Viruses, worms, logic bombs, network attacks, covert channels, steganography, cryptology, authentication, digital signatures, electronic commerce.
Prerequisite: COP 3530, COT 5405. ;
Corequisite: COP 4600.

CNT 5517 Mobile Computing 3 Credits
Grading Scheme: Letter Grade
Emerging topics of wireless and mobile computing and networking including mobile computing models, mobile-IP, adhoc networks, Bluetooth, and 802.11b. Mobile database access and mobile transactions in context of emerging field of M-commerce.
Prerequisite: CNT 4007C.

CNT 6107 Advanced Computer Networks 3 Credits
Grading Scheme: Letter Grade
Computer network architecture, including topologies, media, switching, routing, congestion control, protocols, and case studies.
Prerequisite: COP 5615 , COP 5536 , and CNT 5106C

CNT 6530 Mobile Networking 3 Credits
Grading Scheme: Letter Grade
Concepts of emerging mobile networks architecture, systematic analysis of effects of mobility on network performance, synthetic and data-driven mobility modeling and simulation, behavior analysis in mobile networks, mobile service and application structure, development, implementation, and evaluation. Topics include architecture, geographic routing and query resolution in ad hoc networks, sensor networks, Internet of Things, and vehicular networks.
Prerequisite: COP 3502c or COP 3503c.

CNT 6885 Distributed Multimedia Systems 3 Credits
Grading Scheme: Letter Grade
Design issues; survey of recent advances, including compression, networking, and operating system issues.

COP 5536 Advanced Data Structures 3 Credits
Grading Scheme: Letter Grade
Development of efficient data structures used to obtain more efficient solutions to classical problems, such as those based on graph theoretical models, as well as problems that arise in application areas of contemporary interest.
Prerequisite: Undergraduate data structures.

COP 5556 Programming Language Principles 3 Credits
Grading Scheme: Letter Grade
History of programming languages, formal models for specifying languages, design goals, run-time structures, and implementation techniques, along with survey of principal programming language paradigms.

COP 5615 Distributed Operating System Principles 3 Credits
Grading Scheme: Letter Grade
Concepts and techniques for efficient management of computer system resources.
Prerequisite: COP 4600.

COP 5618 Concurrent Programming 3 Credits
Grading Scheme: Letter Grade
Overview of principles and programming techniques. Reasoning about concurrency, synchronization, program structuring, multi-threaded server applications.
Prerequisite: COP 3100, 3530.

COP 5725 Database Management Systems 3 Credits
Grading Scheme: Letter Grade
Introduction to systems and procedures for managing large computerized databases.
Prerequisite: COP 3530, 4600, or equivalent.

COP 6726 Database System Implementation 3 Credits
Grading Scheme: Letter Grade
DBMS architecture, query processing and optimization, transaction processing, index structures, parallel query processing, object-oriented and object-relational databases, and related topics.
Prerequisite: COP 4600 and 4720 or COP 5725.

COT 5405 Analysis of Algorithms 3 Credits
Grading Scheme: Letter Grade
Introduction and illustration of basic techniques for designing efficient algorithms and analyzing algorithm complexity.
Prerequisite: COP 3530.

COT 5442 Approximation Algorithms 3 Credits
Grading Scheme: Letter Grade
Fundamentals of algorithmic paradigms, analysis, techniques, and software. Topics include greedy methods, randomized algorithms, IP-rounding, approximability, covering, packing, clustering, and network problems.
Prerequisite: COP 3530 or COT 5405

COT 5520 Computational Geometry 3 Credits
Grading Scheme: Letter Grade
Design, analysis, and implementation of algorithms and date structures to solve geometric problems. Applications in graphics, robotics, computational biology, data mining, and scientific computing. Convex hulls, Voronoi diagrams, triangulations, arrangements, and range searching.
Prerequisite: COP 3530.

COT 5615 Mathematics for Intelligent Systems 3 Credits
Grading Scheme: Letter Grade
Mathematical methods commonly used to develop algorithms for computer systems that exhibit intelligent behavior.
Prerequisite: MAC 2313, Multivariate Calculus; MAS 3114 or MAS 4105, Linear Algebra; STA 4321, Mathematical Statistics.

COT 6315 Formal Languages and Computation Theory 3 Credits
Grading Scheme: Letter Grade
Introduction to theoretical computer science including formal languages, automata theory, Turing machines, and computability.
Prerequisite: COP 3530 and familiarity with discrete mathematics and data structures.

EGN 5949 Practicum/Internship/Cooperative Work Experience 1-6 Credits, Max 6 Credits
Grading Scheme: S/U
Practical cooperative engineering work under approved industrial and faculty supervision.
Prerequisite: graduate student.

EGN 6913 Engineering Graduate Research 0-3 Credits, Max 12 Credits
Grading Scheme: S/U
Course will provide the student with supervised research in a laboratory setting.

IDC 5715 Virtual Reality for the Social Good 3 Credits
Grading Scheme: Letter Grade
A multidisciplinary approach to solving pressing social problems by blending social science practices with innovative technology. Students will explore effective messaging perspectives, virtual social spaces, and virtual reality technologies to create a compelling story for a social good issue. This class is for all students, regardless of major/prior experience.