

AI Master of Engineering Courses

Our novel curriculum gives students the skill set they need to build innovative AI-based products and systems

PRE-PROGRAM PREPARATION

AIPI 503: Python & Data Science Bootcamp

This four-week online bootcamp will help you build proficiency in the use of Python for data science as well as basic software engineering principles and tools. It covers foundational concepts and provides hands-on experience with critical skills including loading, cleaning, manipulating, visualizing, analyzing and interpreting data. Upon completion of the bootcamp, you will have the skills to identify, formulate and solve practical data analysis problems using Python.

The first two weekly modules are an introduction to basic Python data structures and control flow. From there, students will build proficiency with three Python libraries critical for data science: NumPy, Pandas, and Matplotlib.

Students who are proficient in Python as well as the data science libraries listed may request to test out of the bootcamp. Waivers are granted at the program director's discretion upon successfully completing the proficiency test.

TECHNICAL CORE

AIPI 510: Sourcing Data for Analytics

In industry, one of the main activities, and challenges, of implementing machine learning applications are collecting data to use in modeling. This course introduces students to methods and tools used for data collection, storage, manipulation, analysis and visualization. The first segment of the course will be an

introduction to numerical programming focused on building skills in working with data via the Numpy and Pandas libraries, two of the most common tools used by teams working with data and modeling. Technical aspects covered will include the types of data, methods of sourcing data via the web, APIs, and from domain-specific sensors and hardware (IoT devices), an increasingly common source of analytics data in technical industries. The course also introduces methods and tools for evaluating the quality of data, performing basic exploratory data analysis, and pre-processing data for use in analytics. Non-technical aspects covered include an introduction to data privacy, GDPR, regulatory issues, bias, and industry-specific concerns regarding data usage.

AIPI 520: Modeling Process & Algorithms

This course is an introduction to the modeling process and best practices in model creation, interpretation, validation, and selection of models for different uses. The primary machine learning algorithms, both supervised and unsupervised, are introduced and students become familiar with both the mathematical theory and the programming application of the models. The primary focus is on statistical learning approaches but the course also introduces deep learning and its applications. At the end of this course, students should have a solid understanding of the end-to-end modeling process and the different types of model algorithms along with the strengths, weaknesses, assumptions, and use cases for each type, and be capable of training and using models in Python. Students who have taken one or more prior machine learning courses in their undergraduate institution will have the option to take an additional technical elective instead of AIPI 520.

AIPI 540: Deep Learning Applications

This course focuses on the primary use cases of deep learning to solve challenging problems particularly in the areas of computer vision, natural language processing and recommendation systems. Students will develop an understanding of both the mathematical theory and programmatic implementation of neural networks using Python. The course includes significant hands-on team-based project work and an emphasis on self-discovery. The semester will be split into three core modules: computer vision, NLP, and recommendation systems. Each module will include lectures, assignments, a team project, and a review of recent research in the field.

AIPI 561: Operationalizing AI (MLOps)

Deploying AI in production requires consideration of factors such as online model training, scaling, integration with software/hardware products, monitoring/support, security and failure resiliency. This course introduces students via real-world case studies to methods and best practices in deploying AI operationally within products and services, including both technology and support infrastructure considerations. The course will also introduce available technologies for working with Big Data in industries that require specialized infrastructure and tools due to the volume of data.

AIPI 501: Industry Seminar Series

Students will attend a weekly seminar series featuring industry leaders discussing the opportunities, challenges and learnings they have gained from applying AI to products and services in their industry. Speakers will present live in-classroom or via video conference. The emphasis in the selection of speakers will be placed on representing more traditional industries that are poised to be disrupted by AI such as agriculture, health care/biotech, energy and environment, and manufacturing. The seminar series will reinforce the concepts learned in the core courses and expand students' intuition for the opportunities to apply AI within more complex and/or traditional industries.

PRODUCT DEVELOPMENT CORE

AIPI 560: Legal, Societal & Ethical Implications of AI

Deploying AI within products and services has implications well beyond the technical considerations, which often include change management of operational workflows or staffing levels, data privacy considerations, bias risks and other ethical implications, and industry-specific regulations on the use of data and models operationally. This course will introduce students to the key areas of consideration when deploying products that contain AI:

1. Legal implications and industry regulation
2. Ethical considerations
3. Change management and organizational/societal implications

Case studies will be used extensively to provide real-world examples.

MENG 540: Management of High-Tech Industries

The purpose of this course is to empower students to become collaborative, ethical leaders in the globalized, 21st-century workplace. Students learn concepts and practice skills that will enable them to transition from being an engineering sole contributor to managing and leading others as a business

professional. Students gain a sound understanding of management and leadership; increase awareness of their own management and leadership styles; build and practice competencies essential for team success (e.g., effective communication, collaboration, conflict resolution); and become ethical leaders above reproach. Emphasis is on leading teams in a volatile, complex and interdependent world.

MENG 570: Business Fundamentals for Engineers

This comprehensive course examines core and evolving concepts in the business fundamentals of successful technology-based companies including Business Plan Development & Strategies, Marketing, Product & Process Development processes, Intellectual Property, Accounting, Finance, and Operations. Students will learn the fundamentals essential to understanding all aspects of a business and will be able to converse in some depth in each of the areas studied upon completion. Other topics will include Supply Chain Management, Stage-Gate Development Cycles, Balances Scorecards, Blue Ocean Strategy, and Disruptive Technologies.

ELECTIVE OPTIONS (SELECT THREE)

Note: In addition to the courses listed below, students in this master's degree program may take other graduate-level elective courses within Duke's Pratt School of Engineering, on a space-available basis with instructor permission. At least one elective must be taken through the AI MEng program.

AIPI Departmental Electives

AIPI 530: Optimization in Practice

Optimization is the ultimate skill in artificial intelligence and prescriptive analytics allowing practitioners to generate the best actionable solutions for business needs. This class will give students required skills to mathematically formulate relevant business problems as optimization models, use leading software modeling syntax and solvers to generate optimum solutions and meaningfully interpret these solutions. We will use both SAS/Optmodel and Python/Pyomo to give student experience with proprietary and open-source optimization software. Focus will be on problem formulation and results interpretation.

AIPI 531: Deep Reinforcement Learning Applications

This course will cover advanced sequential decision-making topics in AI and will consist of two parts: 1) deep reinforcement learning theory and 2) deep reinforcement learning applications. Deep reinforcement learning combines reinforcement learning and deep learning. The theory module will introduce students to major deep reinforcement learning algorithms, modeling process, and programming. The applications module will include case studies on the practical applications of deep reinforcement learning in industry. This is a project-based course with extensive Pytorch/Tensorflow hands-on exercises. Students will also have an opportunity to improve their GitHub profile by working on projects.

AIPI 571 / IDS 721: Data Analysis at Scale in the Cloud

This course is designed to give students a comprehensive view of cloud computing including Big Data and Machine Learning. A variety of learning resources will be used including interactive labs on Cloud Platforms (Google, AWS, Azure). This is a project-based course with extensive hands-on assignments.

AIPI 590-01: Large Language Models for Generative AI

This course focuses on the emerging field of Generative AI with specific emphasis on Large Language Models (LLMs). Both the theory and practical application of LLMs will be covered, with significant hands-on project work. Students will work with LLMs to develop software applications and in the process will gain an understanding of the opportunities, limitations, and practical strategies for implementing generative AI effectively. The course will also explore the nature of generative AI models relative to human intelligence, the role that generative AI plays in the path towards artificial general intelligence (AGI), and the opportunities and risks that the current trajectory of generative AI development is creating.

AIPI 590-02: Applied Computer Vision

Computer vision is a rapidly evolving field with broad applications in industries ranging from healthcare and automotive to entertainment and agriculture. This course is designed to equip students with the knowledge and practical skills required to understand, develop, and deploy deep learning based computer vision systems for solving real-world problems. Students will delve into the fundamental concepts of computer vision, gain hands-on experience with state-of-the-art tools and libraries, and work on projects that tackle real-world challenges. Topics covered include image classification, object detection, segmentation and generation. Emphasis will be placed on building scalable data and modeling pipelines suitable for real-world application.

AIPI 590-03: Emerging Trends in Explainable AI

This course introduces students to emerging trends in XAI (Explainable AI), including Human-AI interaction, ML interpretability and transparency techniques, adversarial attacks and defenses, and red-teaming. Discussions around the regulatory landscape, ethical considerations, and security will be balanced with hands-on experience with emerging tools and approaches in XAI.

Additional Technical Electives

BIOSTAT 709: Observational Studies

Methods for causal inference, including confounding and selection bias in observational or quasi-experimental research designs, propensity score methodology, instrumental variables and methods for non-compliance in randomized clinical trials.

BME 580: Biomedical Data Science

This course will teach a combination of theory and application of biomedical data science principles using multi-scale biomedical data; including multi-omics, wearable sensor, and electronic health records data. Basic principles of data mining, exploratory data analysis, and statistics will be reviewed, and students will be introduced to supervised and unsupervised machine learning and model evaluation and selection methods. Methodology learned in classes will be applied in the assignments and class project to real-world multi-omics, wearable sensor, and electronic health records data.

CYBERSEC 511: Cybersecurity in the Software

Development Lifecycle

Teaches students about all steps of the software development lifecycle and the role Cybersecurity design principles play in requirements definition, design, development, testing, and maintenance. Tools and techniques to provide software security analysis and software assurance will be explored including software reverse engineering.

CYBERSEC 520: Applying Machine Learning to Advance Cybersecurity

The use of machine learning and AI is becoming more prevalent for collecting and analyzing data as its consolidation increases in value. Cyberattacks seek to steal, deny access, misrepresent (such as deepfakes), or compromise the privacy of information. Students will explore the power of machine learning and AI's use in enhancing Cybersecurity tools across the NIST Framework and also in detecting and exploiting vulnerabilities in timeframes and ways heretofore unthinkable.

ECE 564: Mobile App Development

Explores the world of mobile application development with a focus on the needs of engineers. Centered on the Apple environment, with the development environment being on OS X and the target environment being an iOS device- iPad, iPhone, iPod Touch or Apple Watch. Real-world- and context-focused on the common programming patterns for engineers in academia or business- standalone apps, apps connected to other systems, apps connected to the cloud. Covers fundamentals essential to understanding all aspects of app development. Taught in a team environment. Students are required to present their project proposals and deliver an app as a final project.

ECE 663: ML in Adversarial Settings

Machine learning is being widely deployed in many aspects of our society. Our vision is that machine learning systems will become a new attack surface and attackers will exploit the vulnerabilities in machine learning algorithms and systems to subvert their security and privacy. In this course, we will discuss security and privacy attacks to machine learning systems and state-of-the-art defenses against them.

ECE 682D: Probabilistic Machine Learning

Introduction to concepts in probabilistic machine learning with a focus on discriminative and hierarchical generative models. Topics include directed and undirected graphical models, kernel methods, exact and approximate parameter estimation methods, and structure learning. The course assumes a prior background in linear algebra and probability and statistics.

EGRMGMT 575: Software Quality Management

This class will introduce students to five different business personas that play a key role in the software development lifecycle—customer, software engineer, software release/quality manager, customer support engineer, and general manager. The students will better appreciate the perspectives that each of these personas brings to their role and how that affects the

"delivered" quality that customers actually experience. The course will also help students understand how to assess customer business outcomes, expectations and measure customer experience. Finally, the class will provide exposure to current industry practices and include guest speakers who can give real-world examples relevant to software quality management.

EGRMGMT 590-01: Software, Solution & Enterprise Architecture

Students learn the concepts and principles about how a software system is constructed at the highest level. Software architecture is the fundamental design of the entire system. It defines what elements are included in the system, what function each element has, and how each element relates to one another. In short, it is the big picture or overall structure of the whole system, how the enterprise technology system works together. Having a clear design of the overall system as a starting point helps to provide a solid basis for developers to follow and it allows higher productivity and software quality. Students immerse themselves into architecture understanding from multiple perspectives through various UML diagrams including different software architectures frameworks, when and how they are used, their advantages and disadvantages. Software architecture is tied to many practical business concerns. These include the skills and organization of the software engineering team, the needs of the business, the development cycle, and the intent of the software itself.

EGRMGMT 590-03: Software Business Management

In today's world software is pervasive in most if not all companies. A software business is a commercial activity aimed at producing, buying, and selling software products or services. Well-run software companies are known for their high profit margins. This course will focus on understanding the key success factors for software organizations to drive their portfolio strategy by mapping out monetization models, pricing, vendor management, professional services, development & continuous delivery, road mapping & maintenance.

EGRMGMT 590-05: Software Business Management

In today's world software is pervasive in most if not all companies. A software business is a commercial activity aimed at producing, buying, and selling software products or services. Well-run software companies are known for their high profit margins. This course will focus on understanding the key success factors for software organizations to drive their portfolio strategy by mapping out monetization models, pricing, vendor management,

professional services, development & continuous delivery, road mapping & maintenance.

STA 640: Causal Inference

Statistical issues in causality and methods for estimating causal effects. Randomized designs and alternative designs and methods for when randomization is infeasible: matching methods, propensity scores, longitudinal treatments, regression discontinuity, instrumental variables, and principal stratification. Methods are motivated by examples from social sciences, policy and health sciences.

STA 663: Statistical Computation

Statistical modeling and machine learning involving large data sets and challenging computation. Data pipelines and data bases, big data tools, sequential algorithms and subsampling methods for massive data sets, efficient programming for multi-core and cluster machines, including topics drawn from GPU programming, cloud computing, Map/Reduce and general tools of distributed computing environments. Intense use of statistical and data manipulation software will be required. Data from areas such as astronomy, genomics, finance, social media, networks, neuroscience.

INDUSTRY PROJECT

AIPI 549: Industry Project

Students will work in teams of 3-5 to complete a Machine Learning/Artificial Intelligence project for a company sponsor around a real-world problem or opportunity they are facing. The project will require students to put into practice many of the skills learned during the program, including both technical and non-technical. Students will have the opportunity to engage directly with representatives from their company partner organization as well as receive guidance from Duke faculty members over the course of the project. The team will present their final deliverables to a sponsor panel and/or an external review panel.

INTERNSHIP OR PROJECT

MENG 550: Master of Engineering Internship or Project

- Internships are typically 8-12 weeks. The minimum hourly requirement for the internship is 320 hours, equivalent to 8 weeks, 40 hours per

week. Projects require approval from the AIPI program director. Projects must fulfill the same learning objectives as internships. Although students are responsible for finding their own internship, Duke provides an experienced career development team to help with your search.

All internships/projects must:

- Apply engineering principles to solving one or more problems outside the classroom environment
- Define a problem and determine potential solutions
- Appreciate the importance of organizational dynamics and work relationships
- Practice professional communication both written and orally
- Complement material presented in the AIPI courses
- Include a self-assessment upon completion in AIPI 551

MENG 551: Master of Engineering Internship or Project Assessment

This assessment course is the culmination of your internship or project work. You will prepare a substantive assessment of your internship or project experience via a written report and/or oral presentation. A polished analysis should include:

- Problem or task conducted
- Challenges faced
- Solutions incorporated
- Workplace communication and interpersonal relationship critique
- Individual performance review