Required Courses

- Mathematics for AI (3 credits) - Can be waived
- Programming for Data Science (3 credits) - Can be waived
- Introduction to AI (5 credits)
- Machine Learning (5 credits)
- Advanced Machine Learning (3 credits)
- Natural Language Processing (3 credits)
- Computer Vision (3 credits)
- Generative AI and LLMs (3 credits)
- AI Systems (3 credits)
- Big Data Systems
- Ethics and Philosophy of Artificial Intelligence (3 credits)
- AI Governance (3 credits)
- Capstone Project (6 credits over two quarters)
- Electives (3 credits)
    - Information Visualization (3 credits)
    - AI in Cybersecurity (3 credits)
    - Social Network Analysis (3 credist)
    - AI in application area courses (open for options/proposals, it can also be a 3-credit seminar by experts in the field, distributed over a year)

Suggested Plan of Study

First Year		
Fall Quarter	**Winter Quarter**	**Spring Quarter**
ARIN 5300 Artificial Intelligence (5)	**ARIN 5310** Machine Learning (5)	**ARIN 5320** Advanced Machine Learning (3)
CPSC 5070 Programming for Data Science (3) *	**ARIN 5360** AI Systems (3)	**ARIN 5330** Big Data Systems (3)
ARIN 5305 Mathematics for AI (3) *	**ARIN 5410** AI Governance (3)	**ARIN 5520/5510** NLP/Computer Vision (3) +
Second Year		
Fall Quarter	**Winter Quarter**	**Spring Quarter**
ARIN 5810 AI Capstone 1 (3)	**ARIN 5820** AI Capstone 2 (3)	**ARIN 5830** AI Capstone 3 (3)
ARIN 5530 Generative AI and LLMs (3)	AI Elective (3) #	
ARIN 5420 Ethics and Philosophy of AI (3)		

+ One of these courses is required. The other one can be used as an elective

* These courses may be waived

Electives can also be taken during the Spring quarter of the second year. The suggested electives are:

- CYBE 5230: AI & Machine Learning for Cybersecurity (shared with the MS in Cybersecurity)
- DATA 5310: Visualization (shared with MSDS)
- ARIN 5350: Social Media Analytics (can be shared with MSDS)
- DATA 5155: Numerical methods for machine learning (shared with MSDS)
- ARIN 5510/5520: Computer Vision or NLP (the one that is not taken as part of the required courses)

Program Pre-requisites

Students need to have a minimum background in Python programming, calculus (including limit, derivation, integral, series, polar coordination), and foundations of probability theory (including probability axioms, conditional probability, random variables, expectation and variance).

Mathematics for AI

Course Description

The course provides a review and introduction to the mathematical components that are required for artificial intelligence and machine learning courses. The course covers topics in probability theory, linear algebra, and optimization.

Prerequisites

None

Topics

- Topics in Linear Algebra
    - Two-dimensional space and line equation
    - Vector and vector operations (add, multiply, scaling)
    - Matrix and matrix operations (add, multiply, scaling)
    - Determinant
    - Inverse
    - Eigen value and eigen vectors
- Topics in Probability Theory
    - Probability axioms
    - Conditional probability and Bayes' rule
    - Random variables
    - Well-known distributions (Bernoulli, binomial, Poisson, uniform, exponential, and normal)
    - Expectation and variance
- Topics in Optimization
    - Convex optimization
    - Gradient descent

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe basic concepts in linear algebra
2. Calculating all the vector and matrix operations, matrix determinant, eigen values, and eigen vectors
3. Describe basic concepts in probability theory
4. Calculating conditional and unconditional probabilities
5. Calculating random variables' expectation and variance
6. Solving simple optimization problems

Suggestions

Graded Activities

- Exam
- Assignments

Textbook

- M.P.Deisenroth, A.A.Faisal, C.S.Ong, *Mathematics for Machine Learning*, 1st Edition

Artificial Intelligence

Course Description

This course exposes the students to the basic and fundamental concepts of artificial intelligence, with an emphasis on building intelligent agents, environments and systems.

Prerequisites

None

Topics

- Introduction
    - What is intelligence?
    - What is AI?
    - Applications of AI
    - Components of AI (i.e., problem solving, decision-making, reasoning, learning, perception)
- Intelligent Agents
- Search
- Constraint Satisfaction
- Game Theory and Game Playing
- Logical Reasoning
- Knowledge representation
- Probabilistic reasoning
- Simple and complex decisions under uncertainty
- Multi-agent decisions
- Philosophy, ethics, safety, and future of AI

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe basic concepts in artificial intelligence
2. Implement common search algorithms for AI problem solving
3. Implement constraint satisfaction algorithms
4. Describe basic concepts of game theory
5. Implement logical reasoning algorithms
6. Implement probabilistic reasoning models
7. Describe major ethical concerns of AI systems

8. Understand AI literature.
9. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Project

The project will involve solving a practical problem using the AI algorithms discussed in this class.

Textbook

- S. Russel, P. Norvig, *Artificial Intelligence: A Modern Approach*, 4th edition.

Machine Learning

Course Description

This course introduces machine learning foundations, concepts, and algorithms and their applications in analyzing massive amounts of data to find interesting patterns that can be used to assist decision making or provide predictions. Topics include decision trees, Bayesian classification, clustering, sequence clustering, and time series analysis. Students are expected to analyze real-world data.

Prerequisites

Math for AI, Python

Topics

- Introduction
  - Machine learning and Artificial Intelligence
  - Supervised vs unsupervised learning
- Model parameter learning
  - Maximum likelihood estimation (MLE)
  - Maximum a posteriori estimation (MAP)
- Supervised learning
  - K-NN Classification and Regression
  - Regression Models
  - Naïve Bayes Classifier
  - Decision Trees
  - Logistic Regression
  - Support Vector Machines
- Unsupervised learning
  - Hierarchical Clustering
  - K-Means and Density Based Clustering
- Performance improvement
  - Ensemble learning
  - Data Reduction and PCA

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe machine learning algorithms
2. Implement common machine learning algorithms discussed in this class in an appropriate programming language
3. Apply analytic methods to choose an appropriate model and evaluate its effectiveness

4. Select an appropriate model for a problem
5. Understand machine learning literature, with sufficient mathematical and analytical maturity, to maintain professional currency.
6. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Project

The project will involve solving a practical problem using the technologies covered in the course. It involves data gathering, applying learning algorithms using common libraries, drawing conclusions and presenting results effectively. For the project the students need to work with big datasets.

Textbook

Advanced Machine Learning

Course Description

This course covers deep learning and other emerging topics in machine learning. Topics include neural networks, deep learning, introduction on reinforcement learning, and emerging topics in machine learning.

Prerequisites

Machine Learning

Topics

- Neural network
- Deep learning
- Topics in deep learning
    - CNNs and RNNs
    - Auto-encoders
    - Transformers
    - GANs
    - Graph neural networks
- Reinforcement Learning
- Emerging topics in machine learning

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe the key features of reinforcement learning and its differences with other learning models
2. Implementing common reinforcement learning algorithms with a programming language
3. Describe neural network models and learning algorithms.
4. Implement backpropagation algorithm in an appropriate programming language.
5. Using autoencoders, transformers, and other deep learning models to solve appropriate machine learning problems
6. Understand machine learning literature, with sufficient mathematical and analytical maturity, to maintain professional currency.

7. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Project

The project will involve using reinforcement learning and deep learning algorithms.

Textbook

R. S. Sutton and A. G. Barto, *Reinforcement Learning: An Introduction*, 2nd edition.

I. Goodfellow, Y Bengio, A. Courville, *Deep Learning*, MIT Press, 2016.

Artificial Intelligence Systems

Course Description

This course focuses on building AI systems from an engineering perspective. In this course, instead of focusing on models and algorithms, the focus is on building a system, assuming the AI model is provided.

Prerequisites

Machine Learning, Artificial Intelligence

Topics

- Introduction to AI-based Software Systems
- GPUs and their applications in AI
- Designing robust systems with AI components
- Architecture of AI-enabled Systems
- Testing and Test Coverage Tools for AI-based systems
- Detecting poor data quality, poor model quality, and data drift
- Reviewing systems with AI components

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Analyze tradeoffs for designing production systems with AI-components
2. Analyze qualities beyond accuracy such as operation cost, latency, updateability, and explainability
3. Design scalable data infrastructures for learning models and experimentation
4. Reason about how to ensure quality of the entire AI pipeline
5. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Textbook

Goeff Hulten, Building Intelligent Systems: A Guide to Machine Learning Engineering, 2018.

Natural Language Processing

Course Description

This course explores the field of natural language processing or NLP, which is about processing the text and speech in a human (natural) language. In this course, students are exposed to various levels of NLP, from simple techniques such as bag-of-words models to structural representations of syntax and semantic analysis.

Prerequisites

Machine Learning

Topics

- Introduction
    - NLP with Python
- Basic models
    - Processing raw text and Bag-of-words
- Extracting information from text
- Machine learning for text classification
- Applications of text classification
    - Sentiment analysis and word sense disambiguation
- Language models
- Analyzing sentence structure and meaning
- Annotating linguistic structures
- NLP Applications

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Identify suitable representation models for natural language problems.
2. Describe algorithms and machine learning techniques for reasoning and processing of linguistic data.
3. Implement NLP algorithms in an appropriate programming language.
4. Evaluate, validate, optimize, and fine-tune NLP systems performance and accuracy.

5. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Project

The project will involve implementing an end-to-end NLP system for a particular NLP application. It involves data gathering, applying learning algorithms using common libraries, drawing conclusions and presenting results effectively.

Textbook

- D. Jurafsky, J. H. Martin, *Speech and Language Processing*, 2024.
- S. Bird, E. Klein, and E. Loper, *Natural Language Processing with Python: Analyzing Text with the Natural Language Toolkit*, 2009.

Computer Vision

Course Description

This course explores the area of computer vision from theory to applications. Topics include camera models, multi-view geometry, reconstruction, some low-level image processing, and high-level vision tasks like image classification and object detection.

Prerequisites

Machine Learning

Topics

- Introduction
- Image formation
    - Camera models
- Image processing / descriptors
    - Hough Transforms
    - Frequency domain analysis
    - Feature detection
    - Feature descriptors
- Image warping
- Linear models
- Motion and flow
- Single-view geometry
- Multi-view geometry
- Applications

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe various image processing and image descriptors.
2. Extract features from images in an appropriate programming language.
3. Implement an end-to-end computer vision system in an appropriate programming language.
4. Evaluate, validate, optimize, and fine-tune computer vision systems performance and accuracy.

5. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Project

The project will involve implementing an end-to-end computer vision system for a particular application.

Textbook

- D. Jurafsky, J. H. Martin, *Speech and Language Processing*, 2024.
- S. Bird, E. Klein, and E. Loper, *Natural Language Processing with Python: Analyzing Text with the Natural Language Toolkit*, 2009.

Generative AI and Large Language Models

Course Description

This course covers foundations of generative AI models and their applications in engineering, design, science, and beyond. The course also covers large language models (LLM) and the related state-of-the-art technologies, including their architecture, variants, and prompt engineering.

Prerequisites

Advanced Machine Learning

Artificial Intelligence Systems

Topics

- Introduction to Generative Models
- Normalizing Flow Model
- Neural Text Decoding
- Information Lattice Learning
- Neural Cellular Automata
- Text, image and sound generation
- Large Language Models
- Model training and fine tuning
- Open-Source large language models
- Prompt Programming
- Detection of Generated Content
- Best practices and ethical considerations
- Emerging trends

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe the fundamental concepts, principles and technology of generative AI.
2. Describe the applications across various industries.
3. Use prompt engineering effectively with respect to the application.
4. Implementing simple generative AI applications.
5. Describe ethical considerations and challenges associated with generative AI.

6. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Project

The project will involve implementing a simple generative AI application with or without open-source libraries.

Information Visualization

Course Description

This course introduces techniques and algorithms for creating effective visualizations based on principles from graphic design, visual art, perceptual psychology, and cognitive science.

Prerequisites

None

Topics

- Data and image models
- Visualization design
- Exploratory data analysis
- Multidimensional data
- Graphical perception
- Visualization software and libraries
- Text visualization
- Networks visualization
- Interaction

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe key techniques and theory used in visualization
2. Perform visualization for solving problems in common data domains (multidimensional data, networks, text)
3. Conduct visualization using software and libraries

Suggestions

Graded Activities

- Exam
- Assignments
- Project

AI Governance

Course Description

This course will present an overview of legal and political tools to foster, direct and contain technological innovation. While artificial intelligence has a wide range of applications and benefits, it can also have harmful consequences, especially for members of vulnerable communities along the lines of class, race, gender, ability and immigration status. Addressing the negative social impact of AI requires sustained efforts from social movements, researchers and politicians striving for social justice. This course will explore the actors, processes and outcomes of these efforts to build technology safely and responsibly.

Prerequisites

None

Topics

- Introduction
    - AI Ethics, Public Good
    - Responsible AI
    - AI Governance Landscape
- Critical Science and Technology Studies
- History of Technology and Resistance
- Theories of Technology Policymaking
- Regulating AI
    - Laws and Policies in US
    - Laws and Policies in EU
    - Frameworks by leading private companies
- Future of AI Governance

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe core principles, challenges, and developments in AI governance.
2. Analyze emerging AI governance strategies, critically assessing their origins, applications, and effectiveness for responsible AI management and regulation.
3. Evaluate the social impact of existing and emerging AI applications in real-world scenarios.

Suggestions

Graded Activities

- Exam
- Assignments
- Term paper

Philosophy and Ethics of AI

Course Description

This course explores various aspects of philosophy of mind, philosophy of AI, and ethical considerations in artificial intelligence.

Prerequisites

None

Topics

- Philosophy of mind
    - Mind as Immaterial Substance
    - Mind as the Brain
    - Mind as a Computing Machine
    - Mind as a Causal System
    - Consciousness and the Mind-Body Problem
- Philosophy of AI
    - What is AI?
    - Language, creativity, emption
    - Singularity
- Ethics of AI
    - Fairness, Bias, and Justics
    - Accountability
    - Transparency
    - Democracy
    - Human dignity
    - Privacy
    - Sustainability
    - AI ethics and regulations

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Being capable of reading philosophy literature and analyzing their argumentation related to philosophy of AI
2. Being able to develop philosophical arguments related to artificial intelligence

3. Describing various ethical considerations related to AI

Suggestions

Graded Activities

- Exam
- Assignments
- Term papers

Textbook

- Kim, *Philosophy of Mind,* 2011.
- Boden, *AI: Its Nature and Future,* 2016.
- M. Coeckelbergh, *AI Ethics*, MIT Press, 2020

AI Capstone Project 1 & 2 & 3

Course Description

Teams of three to four students solve an AI problem from definition to implementation and presentation. Problems are preferred to be industrially sponsored; however, they may be proposed by the instructor too. Students will be expected to define the problem scope, obtain and prepare data sets, do the required implementations, tests, and analyses and present results effectively.

Prerequisites

Advanced Machine Learning

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

- Design, implement, and test a substantial AI project
- Choose, apply, and evaluate appropriate algorithms and technologies to solve the problem
- Function effectively on teams to establish goals, plan tasks, meet deadlines, manage risk, and produce deliverables
- Effectively communicate results and technical concepts in written, oral, and graphical/visual modalities

Artificial Intelligence and Cybersecurity

Course Description

With the growing importance of AI and cybersecurity technologies, there is a growing connection between these two fields. On one hand, deployment of AI in any application requires assurance that it maintains security and privacy goals. On the other hand, AI can be used to improve cybersecurity systems. This course explores the application of AI in cybersecurity and the security of AI systems.

Prerequisites

None

Topics

- Introduction
    - Review of AI and ML main concepts
    - Review of cybersecurity main concepts
- AI for Threat Detection and Prevention
- Privacy preserving AI techniques
- Data protection compliance
- Securing AI models
- AI and Data Security
- Future Trends and Challenges

Course Learning Outcomes

On successful completion of this course (i.e. by passing this course), you will be able to

1. Describe the fundamental concepts of Machine Learning and Artificial Intelligence in the context of cybersecurity
2. Deploy AI/ML tools and algorithms for different cybersecurity applications.
3. Describe the security and privacy issues of AI systems
4. Evaluate an AI systems to comply with security and privacy requirements

Suggestions

Graded Activities

- Exam
- Assignments
- Project

Project

The project will involve programing and design tasks to solve a cybersecurity problem using AI techniques and/or design an AI system with security and privacy considerations.

Textbook

- R.R.Palle, K.C.R.Kathala, *Privacy in the Age of Innovation: AI Solutions for Information Security*, Apress, 2024

Social Network Analytics

Course Description

This course introduces concepts and algorithms required for analysis of social networks and data available on social media. The course introduces Web techniques, social networks and analysis, network analysis and graph theory, information extraction, link analysis, and community analysis to study emerging problems with social media.

Prerequisite

Introduction to Artificial Intelligence and Machine Learning

Topics

- Introduction
- Graph theory essentials
- Network measures
- Community Analysis
- Information Diffusion in Social Media
- Recommendation in Social Media
- Behavior Analytics
- Privacy and security in social networks

Course Learning Outcomes

1. Describing the fundamental concepts in social media analytics.
2. Use mathematical techniques to model and analyze structural and dynamical properties of social networks.
3. Implement and apply simulation and/or data mining methods and algorithms to investigate a particular social phenomenon.
4. Describing different graph similarity metrics and their proper applications.
5. Describing privacy issues in social media analytics

Suggestions

Graded Activities:

- Exams
- Assignments
- Project

Big Data Systems

Course Description

This course covers the Hadoop architecture and the Hadoop ecosystem of tools. Students will learn to apply Hadoop and related Big Data technologies such as MapReduce, and Spark in developing analytics and solving problems that process vast quantities of data.

Prerequisite

TBD

Topics

- Overview of Hadoop and Hadoop Ecosystem
- MapReduce programming model
- Common MapReduce algorithms
- Debugging and testing for MapReduce programs
- Spark basics
- Spark SQL, DataFrames, MLib
- If time permits, optimization of Spark jobs will be discussed.

Course Learning Outcomes

1. Understand the architecture of Hadoop
2. Perform big data analysis with MapReduce
3. Perform big data analysis with Spark
4. Solve big data analytics problems in course projects
5. Communicate the methods, results, and findings appropriately in writing and verbally.

Suggestions

Graded Activities:

- Exams
- Assignments
- Project