# CS4489: OPTIMIZATION FOUNDATIONS FOR AI TRAINING

## New Syllabus Proposal

---

**Effective Term**

Semester A 2025/26

## Part I Course Overview

**Course Title**

Optimization Foundations for AI Training

**Subject Code**

CS - Computer Science

**Course Number**

4489

**Academic Unit**

Computer Science (CS)

**College/School**

College of Computing (CC)

**Course Duration**

One Semester

**Credit Units**

3

**Level**

B1, B2, B3, B4 - Bachelor's Degree

**Medium of Instruction**

English

**Medium of Assessment**

English

**Prerequisites**

CS2402 Introduction to Computational Probability Modeling or
CS4486 Artificial Intelligence

## Part II Course Details

**Abstract**

This course offers an accessible introduction to the optimization foundations (both theoretical and programmatic) essential for artificial intelligence (AI) training and machine learning (ML). The course bridges elementary concepts in computer science with practical training techniques essential for developing modern AI systems. Through these tools, students will build a solid foundation for deeper exploration of AI and ML, gaining critical insights into contemporary AI development.

**Course Intended Learning Outcomes (CILOs)**

| | CILOs | Weighting (if app.) | DEC-A1 | DEC-A2 | DEC-A3 |
|---|---|---|---|---|---|
| 1 | Understand key mathematical concepts in optimization theory and machine learning. | | x | x | |
| 2 | Formulate AI training problems as optimization problems, and identify key steps in the training procedure. | | x | x | |
| 3 | Evaluate the effectiveness and efficiency of different algorithms to perform AI training. | | | x | |
| 4 | Apply optimization algorithms to train AI/ML models. | | | x | |

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

**Learning and Teaching Activities (LTAs)**

| | LTAs | Brief Description | CILO No. | Hours/week (if applicable) |
|---|---|---|---|---|
| 1 | Lecture | Students will be taught the basic theories of optimization in AI, and the different tools/algorithms in AI training. The algorithms and theories will be derived rigorously with supporting toy and real-world examples. | 1, 2, 3, 4 | 3 hours per week |
| 2 | Tutorials | Each weak's tutorial will discuss several questions related to key concepts learned in the previous lecture. | 1, 2, 3, 4 | 8 hours per semester |
| 3 | Homework | Students will test their understanding on the knowledge learned in lectures, and try to apply them using Python code. | 1, 2, 3, 4 | |
| 4 | Midterm | Students will be tested on their theoretical understandings of this course. | 1, 2, 3 | |

**Assessment Tasks / Activities (ATs)**

| | ATs | CILO No. | Weighting (%) | Remarks ("-" for nil entry) | Allow Use of GenAI? |
|---|---|---|---|---|---|
| 1 | Homework Assignment | 1, 2, 3, 4 | 30 | - | Yes |
| 2 | Midterm | 1, 2, 3 | 30 | - | No |

**Continuous Assessment (%)**

60

**Examination (%)**

40

**Examination Duration (Hours)**

2

**Minimum Examination Passing Requirement (%)**

30

**Additional Information for ATs**

For a student to pass the course, at least 30% of the maximum mark for the examination must be obtained.

**Assessment Rubrics (AR)**

**Assessment Task**

Homework Assignments

**Criterion**

Able to solve analytical tasks related to basic mathematical theories and optimization methods.

**Excellent (A+, A, A-)**

Excellent if the assignment has mostly correct solution, and demonstrates mastery of class concepts beyond given examples.

**Good (B+, B, B-)**

Good if the assignment has partially correct solution, and demonstrates mastery of class concepts for examples that has been given by course instructors.

**Fair (C+, C, C-)**

Fair if the assignment has some correct solution, and demonstrates basic understanding of course concepts.

**Marginal (D)**

Marginal if the assignment has very little correct solution, and demonstrates only limited understanding of selected concepts.

**Failure (F)**

Not reaching marginal levels.

---

**Assessment Task**

Midterm Exam

**Criterion**

Able to solve theoretical questions related to mathematical tools and optimization theory.

**Excellent (A+, A, A-)**

Excellent if the exam contains mostly correct solution, and demonstrates mastery of class concepts beyond given examples.

**Good (B+, B, B-)**

Good if the exam contains partially correct solution, and demonstrates mastery of class concepts for examples that has been given by course instructors.

**Fair (C+, C, C-)**

Fair if the exam contains some correct solution, and demonstrates basic understanding of course concepts.

**Marginal (D)**

Marginal if the exam contains very little correct solution, and demonstrates only limited understanding of selected concepts.

**Failure (F)**

Not reaching marginal levels.

---

**Assessment Task**

Final Exam

**Criterion**

Able to solve theoretical questions related to mathematical tools and optimization theory.

**Excellent (A+, A, A-)**

Excellent if the exam contains mostly correct solution, and demonstrates mastery of class concepts beyond given examples.

**Good (B+, B, B-)**

Good if the exam contains partially correct solution, and demonstrates mastery of class concepts for examples that has been given by course instructors.

**Fair (C+, C, C-)**

Fair if the exam contains some correct solution, and demonstrates basic understanding of course concepts.

**Marginal (D)**

Marginal if the exam contains very little correct solution, and demonstrates only limited understanding of selected concepts.

**Failure (F)**

Not reaching marginal levels.

---

# Part III Other Information

**Keyword Syllabus**

AI Training, Machine Learning, Optimization, Linear Algebra, Gradient Descent, Generative AI, Transformers, Backpropogation, Automatic Differentiation, PyTorch, Deep learning, learning rate, convergence, double descent.

Syllabus:

Part 1, Review of Tools

Lecture 1: Review of vectors and matrices, and 1D calculus.

Lecture 2: Introduction to gradient, Jacobian, and Hessian.

Lecture 3: Taylor’s theorem (1D and higher-dimensional) and multivariate chain rule.

Part 2, AI training fundamental
Lecture 4: Formulation of optimization problems. Identify convex vs non-convex problems.
Lecture 5: Introduction to gradient descent.
Lecture 6: Introduction to neural networks and forward pass.
Lecture 7: Gradient of neural networks and back-propagation.
Lecture 8: Python basics. Apply auto-differentiation packages in Python to train neural networks.
Part 3, Advanced Training
Lecture 9: Learning rate and hyper-parameter tuning.
Lecture 10: Introduction to Stochastic Gradient Descent.
Lecture 11: Modern optimizers like Adam and how to use them in Python.
Lecture 12: Case study of training GenAI.

**Reading List**

**Compulsory Readings**

| | Title |
|---|---|
| 1 | Boyd, Stephen, and Lieven Vandenberghe. Introduction to applied linear algebra: vectors, matrices, and least squares. Cambridge university press, 2018. |
| 2 | Wright, Stephen J., and Benjamin Recht. Optimization for data analysis. Cambridge University Press, 2022. |

**Additional Readings**

| | Title |
|---|---|
| 1 | Wasserman, Larry. All of statistics: a concise course in statistical inference. Springer Science & Business Media, 2013. |