The Hong Kong University of Science and Technology (Guangzhou)

UG Course Syllabus Template

Course Title: Mathematics for AI

Course Code: AIAA 2711

No. of Credits: 3

Any pre-/co-requisites: UFUG 1103 or UFUG 1106

It is highly recommended to attend linear algebra before participating in this course !

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Course Description

This course aims to teach students the basic math concepts for Artificial Intelligence. Key topics include fundamental Linear Algebra (Matrix Calculations, Norms, Eigenvectors and Eigenvalues), Calculus (Derivative, Taylor series, Multivariate Calculus), and Probability Theory (Distributions, Statistics of Random Variables, Bayes' theorem). With these mathematical concepts, some basic principles of numerical optimization and typical AI algorithms (Gradient Descent, Maximum-likelihood, Regression, Least Square Estimation, Spectral Clustering, Matrix Decomposition, etc.) will also be introduced as examples to better relate math to AI. The approach of this course is specifically Artificial Intelligence application oriented, aiming to help students to quickly establish a fundamental mathematical knowledge structure for AI studies. Through this course, students will acquire the fundamental mathematical concepts required for AI, understand the connections between AI and mathematics, and get prepared to learn the mathematical principles, formulas, inductions, and relevant proofs for advanced AI algorithms.

Intended Learning Outcomes (ILOs)

By the end of this course, students should be able to:

1. Demonstrate fundamental understanding of Linear Algebra
2. Demonstrate fundamental understanding of Multivariate Calculus and Optimization
3. Demonstrate fundamental understanding of Probability Theory
4. Demonstrate fundamental understanding of the principle of several typical AI algorithms
5. Understand the mathematical foundations of easy AI algorithms through self-learning

Course Schedule

- Week 1: Linear Algebra: Systems of Linear Equations, Matrices, Vector Spaces, Linear Independence – ILOs: 1
- Week 2: Linear Algebra: Basis and Rank, Linear Mappings, Affine Spaces – ILOs: 1
- Week 3: Analytic Geometry: Norms, Inner Products, and Lengths and Distances, Angles and Orthogonality – ILOs: 1
- Week 4: Analytic Geometry: Orthonormal Basis, and Orthogonal Complement, Inner Product of Functions, Orthogonal Projections, Rotations – ILOs: 1
- Week 5: Matrix Decompositions: Determinant and Trace, Eigenvalues and Eigenvectors, Cholesky Decomposition, Eigendecomposition and Diagonalization – ILOs: 1, 4
- Week 6: Matrix Decompositions: Singular Value Decomposition, Matrix Approximation – ILOs: 1, 4
- Week 7: Vector Calculus: Differentiation of Univariate Functions, Partial Differentiation and Gradients, Gradients of Vector-Valued Functions, Gradients of Matrices, Useful Identities for Computing Gradients – ILOs: 2
- Week 8: Vector Calculus: Backpropagation and Automatic Differentiation, Higher-Order Derivatives, Linearization and Multivariate Taylor Series — Continuous Optimization: Optimization Using Gradient Descent – ILOs: 2, 4
- Week 9: Continuous Optimization: Constrained Optimization and Lagrange Multipliers, Convex Optimization — Probability and Distributions: Sum Rule, Product Rule, and Bayes' Theorem, Means and Covariances, Statistical Independence – ILOs: 2, 3, 4
- Week 10: Probability and Distributions: Sums and Transformations of Random Variables, Gaussian Distribution, Sums and Linear Transformations, Change of Variables/Inverse Transform
- Week 11, 12: Project Presentations – ILOs: 1, 2, 3, 4, 5

Assessment and Grading

This course will be assessed using criterion-referencing and grades will not be assigned using a curve. Detailed rubrics for each assignment are provided below, outlining the criteria used for evaluation.

Assessments

Assessment Task	Contribution to Overall Course grade (%)	Due date
In-class test (closed book)	10%	During every lecture*
Course Participation	20%	During every lecture
Group Project	30%	dd/mm/yyyy *
Final Examination	40%	dd/mm/yyyy

* Assessment marks for individual assessed tasks will be released within two weeks of the due date.

Assessment(s) Grading Rubrics

In-class test (10%) – Closed book

- Graded strictly against provided answer keys
- Final grade is the average of all in-class test scores

Course Participation (20%)

- Based on attendance and discussion participation at each lecture.

- Total grade is proportional to the percentage of lectures attended.

Group Project (30%) – Teams of 3 students

- Presentation (15%): Evaluated by instructor, GTAs, on clarity, accuracy, and delivery.
- Report (15%): Graded on completeness, clarity, accuracy, and formatting correctness.

Final Examination (40%) – Closed book

- Up to 80% of the points for a question can be earned if the final answer is incorrect, provided the reasoning, solution steps, and underlying conceptual understanding are clearly demonstrated.

Mapping of Course ILOs to Assessment Tasks

Assessed Task	Mapped ILOs	Explanation
In-class test	ILO1, ILO2, ILO3, ILO4	Through independent problem-solving at the end of each class, students will showcase their comprehension and ability to implement the concepts discussed in the lessons. Therefore, this task assesses students' ability to solve problems in linear algebra (ILO1), multivariate calculus and optimization (ILO2), probability theory (ILO3), and typical AI algorithm(ILO4), depending on the content for the specific lecture.
Course Participation	ILO1, ILO2, ILO3, ILO4	Course participation is crucial for students to master the content of the course, therefore corresponding to ILO1-ILO4.
Group Project	ILO1, ILO2, ILO3, ILO4, ILO5	Students need to work in group and prepare a demonstration of a selected AI-related mathematical concept in a clear and easy way to show comprehensive understanding of the concept. Additionally, a report to describe the preparation and the application of the selected concepts in AI is also needed. This evaluates the students' ability to learn a new mathematical concept based on what the have learned during the course, therefore corresponding to ILO1-ILO5.
Final examination	ILO1, ILO2, ILO3, ILO4	The final examination serves as a comprehensive assessment of the course content, evaluating students' ability to solve problems in linear algebra, multivariate calculus and optimization, probability theory, and typical AI algorithm, therefore corresponds to ILO1-ILO4.

Final Grading Rubrics

A+ : [100, 96] | A : (96, 92] | A- : (92, 88] | B+ : (88, 84] | B : (84, 80] | B- : (80, 76] | C+ : (76, 72] | C : (72, 68] | C- : (68, 64] | D : (64, 60] | F : (60, 0].

Final Grade Descriptors:

Grades	Short Description	Elaboration on subject grading description

A	Excellent Performance	The student demonstrates an exceptional understanding of linear algebra, multivariate calculus, probability theory, and AI algorithms. They exhibit outstanding problem-solving skills, consistently applying mathematical concepts creatively and effectively in AI contexts. Their participation and contributions in class are insightful. The group project reflects a deep understanding and an innovative approach to AI-related mathematical concepts, showcasing their ability to learn independently and apply new knowledge. Their performance in assessments consistently exceeds expectations, showing a comprehensive mastery of all intended learning outcomes.
B	Good Performance	The student shows a solid grasp of the core mathematical concepts and AI algorithms. They effectively solve problems and analyze issues, demonstrating a strong motivation to learn. Their participation in class is active and constructive, and they work well in group settings, contributing meaningfully to the group project. The project and assessments reflect a good understanding of the course material, with occasional creativity and insight. They meet the learning objectives, showing competence in applying mathematical principles to AI problems.
C	Satisfactory Performance	The student possesses an adequate understanding of the essential mathematical concepts and AI algorithms. They can handle familiar problems and demonstrate some analytical and critical thinking skills. Class participation is consistent, and they contribute to the group project, though their work may lack depth or originality. Their performance in assessments indicates a satisfactory grasp of the course material, achieving the learning outcomes at a basic level.
D	Marginal Pass	The student shows a minimal understanding of the core mathematical concepts and AI algorithms, meeting only the basic course requirements. They struggle with problem-solving and critical analysis but demonstrate potential in developing these skills. Participation in class and group work is limited, but they show some effort in engaging with the material. Their assessments reflect a marginal ability to achieve the intended learning outcomes, requiring further development to fully grasp the subject matter.
F	Fail	The student demonstrates insufficient understanding of the mathematical foundations and AI algorithms covered in the course. They lack the necessary problem-solving skills and exhibit minimal effort towards class participation and group work. Their assessments show a failure to meet the basic learning objectives, with little evidence of analytical or critical thinking. Overall, they do not meet the threshold requirements for understanding or applying the course content.

Course AI Policy

Three principles for using (generative) AI in the course:

- **Always Acknowledge AI Contributions:** When AI tools are deployed in coursework, it is essential to always cite and acknowledge their contributions Transparency in the use of AI not only upholds academic integrity but also provides clarity on the sources of information and insights.

- **Always Critically Evaluate AI-Generated Information:** AI tools can be powerful resources, but their outputs must be always assessed for accuracy and relevance It is important to verify the information generated by AI against credible sources and apply independent judgment to ensure its validity and reliability in the coursework.
- **Always Prioritize Academic Integrity:** AI should always only serve as a supplementary tool in the learning and research process, but not replacing personal efforts, understanding, and analysis in the coursework.

Communication and Feedback

- Primary Course Platform: Canvas will be used for all announcements, course materials, assignment submissions, and grade releases.
- Feedback on Assessed Work: Marks and detailed feedback for assignments will be released via Canvas within two weeks of the submission deadline. Feedback will include written comments on strengths and areas for improvement.
- Questions About Feedback: Students with questions about their marks or feedback should contact the instructor within five working days after the feedback is released.
- Contact & Consultation: For questions or to schedule a meeting, please email the instructor. Office consultations are held in W4–311 and can be arranged at a mutually convenient time after email coordination.
- Response Time: The instructor and TAs aim to respond to emails within 48 hours on weekdays.

Student Feedback & Improvement

Student feedback is essential to the continuous improvement of this course. Students are encouraged to provide:

- Mid-Term Feedback: An anonymous mid-term feedback opportunity will be provided around Week 7. This informal feedback helps the instructor make timely adjustments to better support your learning experience.
- Student Feedback Questionnaire (SFQ): At the end of the term, you will receive an invitation to complete the official university SFQ. Your honest and constructive feedback is highly valued and directly informs future iterations of this course.

Resubmission Policy

Resubmission is not allowed.

Required Texts and Materials

- Mathematics for machine learning. Deisenroth, M.P., Faisal, A.A. and Ong, C.S., 2020. Cambridge

Academic Integrity

Students are expected to adhere to the university's academic integrity policy. Students are expected to uphold HKUST(GZ)'s Academic Honor Code and to maintain the highest standards of academic integrity. The

University has zero tolerance of academic misconduct. Please refer to Regulations for Academic Integrity and Student Conduct for the University's definition of plagiarism and ways to avoid cheating and plagiarism.

[Optional] Additional Resources

1. University Press, https://mml-book.github.io/ 神经网络与深度学习. 邱锡鹏, 机械工业出版社, https://nndl.github.io/
2. Russell, S.J. and Norvig, P., 2016. Artificial intelligence: a modern approach, Pearson.