The Hong Kong University of Science and Technology (Guangzhou)

UG Course Syllabus Template

[Course Title] : Mathematics for AI

[Course Code]: AIAA2711

[No. of Credits]: 3

[Any pre-/co-requisites] [(Calculus IA OR Calculus IB OR Honors Calculus I) AND (Calculus II OR Honors Calculus II)] OR [Accelerated Calculus]

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

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Venue: Rm 101, E1

Time: Friday 9:00-10:20am, Monday 1:30-2:50pm

Office Hours: Every Monday 7:30pm-9:30pm, W4-305 (Instructor's office)

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

Weekly Schedule

Date	Content	Mapped ILOs
Jan. 23	Introduction to the course, Group, Vector Space	ILO1,ILO4
Jan. 26	Linear Combination, Spanning and Dimension of Space, Linear Mapping	ILO1,ILO4
Jan. 30	Affine Space, Norm	ILO1,ILO4
Feb. 2	Inner Product and Positive Definite	ILO1,ILO4
Feb. 6	Distance and Angle, Orthonormal Basis, Inner Product of Function	ILO1,ILO4
Feb. 9	Projections of Vectors, Gram-Schmidt Orthogonalization and Rotation	ILO1,ILO4
Feb. 27	Gram-Schmidt Orthogonalization and Rotation	ILO1,ILO4
Mar. 2	Eigenvalue and Eigen Vector, Eigendecomposition and Diagonalization	ILO1,ILO4
Mar. 6	Singular Value Decomposition, Cholesky Decomposition	ILO1,ILO4
Mar. 9	Matrix Approximation	ILO1,ILO4
Mar. 13	Differentiation and Gradient	ILO2,ILO4
Mar. 16	Grandients of Vector-Valued Functions and Matrices	ILO2,ILO4
Mar. 20	Automatic Differentiation	ILO2,ILO4
Mar. 23	Backpropagation and vanishing (exploding) gradient	ILO2,ILO4
Mar. 27	Unconstrained, Gradient Descent with Momentum, Stochastic Gradient Descent	ILO2,ILO4
Mar. 30	Constrained Optimization, Primal and Dual Problems	ILO2,ILO4
Apr. 3	Convex sets, Convex Function, Convex Optimization,Linear Programming and Quadratic Programming	ILO2,ILO4
Apr. 10	Sum and Product Rule, Bayes' Theorem	ILO3,ILO4
Apr. 13	Expectation, Mean, Covariance, and Statistical Independence	ILO3,ILO4

Apr. 17	Single- and Multi-variables Gaussians Distribution, Marginals and Conditionals of Gaussians, Sums and Linear Transformations of Gaussian, Change of Variables	ILO3,ILO4
Apr. 20	Advance Topics in AI	ILO1, ILO2, ILO3, ILO4
Apr. 24	Project Demo 1	ILO1, ILO2, ILO3, ILO4, ILO5
Apr. 27	Project Demo 2	ILO1, ILO2, ILO3, ILO4, ILO5
May. 8	Project Demo 3	ILO1, ILO2, ILO3, ILO4, ILO5
May 11	Project Demo 4	ILO1, ILO2, ILO3, ILO4, ILO5

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:

[List specific assessed tasks, exams, quizzes, their weightage, and due dates; perhaps, add a summary table as below, to precede the details for each assessment.]

Assessment Task	Contribution to Overall Course grade (%)	Due date
In-class test	10%	Will be performed in class
Course Participation	20%	Will be evaluated in each lecture
Group Project	30%	May 11th,2026
Final examination	40%	To be announced

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

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.

Grading Rubrics

1. Course participation will be graded according to students' attendance to each lecture, considering the documented record for lecture exercise and in-class test. The total grade will be given according to the percentage of lecture that students have attended.

2. In-class tests will be graded strictly based on the provided answers. The final grade will be given according to the averaged scores of all in-class test.

3. Group project will be graded based on the presentation (15%) and the report(15%). Presentation will be graded according to the evaluation and feedback from the audiences (the instructor, GTAs, and students) from clarity and accuracy of the presentation. The report will be graded according to the completeness, clarity, accuracy, and correctness in format.

4. For final exam, 80% of the total grade can still be earned if the final answer is incorrect, provided the reasoning, solution steps and the underlying physical concepts are correct.

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-always 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

Assessment marks for individual assessed tasks will be communicated via Canvas within two weeks after the submission deadline. Feedback on assignments will include the grades of the assessment. Students who have further questions about the feedback including marks should consult the instructor within five working days after the feedback is received.

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. Artificial intelligence: a modern approach. Russell, S.J. and Norvig, P., 2016. Artificial intelligence: a modern approach, Pearson.