**City University of Hong Kong**
**Course Syllabus**

**offered by Department of Computer Science**
**with effect from Semester A 2022/23**

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## Part I Course Overview

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|---|---|
| **Course Title:** | Machine Learning: Principles and Practice |
| **Course Code**: | CS5487 |
| **Course Duration:** | One semester |
| **Credit Units**: | 3 credits |
| **Level**: | P5 |
| **Medium of Instruction:** | English |
| **Medium of Assessment:** | English |
| **Prerequisites**: *(Course Code and Title)* | CS3334 Data Structures<br>AND<br>[MA2176 Basic Calculus and Linear Algebra or<br>MA2170 Linear Algebra & Multi-variable Calculus or<br>MA2172 Applied Statistics for Sciences & Engineering] |
| **Precursors**: *(Course Code and Title)* | Nil |
| **Equivalent Courses**: *(Course Code and Title)* | Nil |
| **Exclusive Courses**: *(Course Code and Title)* | Nil |

## Part II Course Details

### 1. Abstract

The goal of this course is for students to learn the fundamental knowledge needed to design machine learning algorithms. Machine learning algorithms allow computers to automatically learn to recognize complex patterns from empirical data, such as text and web documents, images, videos, sound, sensor-data, and databases. This course is intended to give a broad overview of machine learning with a focus on fundamental design, derivation, and implementation of machine learning algorithms. At the end of the course, students will have fundamental knowledge needed to design and implement new machine learning algorithms from first principles.

### 2. Course Intended Learning Outcomes (CILOs)

*(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)*

| No. | CILOs | Weighting (if applicable) | Discovery-enriched curriculum related learning outcomes (please tick where appropriate) | | |
|---|---|---|---|---|---|
| | | | *A1* | *A2* | *A3* |
| 1. | Identify, explain, and derive common machine learning algorithms from first principles. | | | | |
| 2. | Implement machine learning algorithms and apply them to solve real-world problems. | | ✓ | | |
| 3. | Analyze and evaluate the effectiveness of different machine learning algorithms, and assess their relative merits. | | ✓ | | |
| 4. | Design and create new machine learning algorithms to address algorithmic shortcomings and solve particular problems. | | | ✓ | ✓ |
| | | 100% | | | |

*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 self-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.*

## 3. Teaching and Learning Activities (TLAs)

*(TLAs designed to facilitate students' achievement of the CILOs.)*

| TLA | Brief Description | CILO No. | | | | Hours/week (if applicable) |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | |
| Lecture | The lectures will present selected machine learning algorithms, and their intuition, design principles, and derivations. The algorithms will be illustrated with both toy and real-world examples to motivate the students' understanding. Implementation details will also be discussed. | ✓ | | ✓ | | 2 hours/week |
| Tutorial | Each week, students will work on problem sets during the tutorial sessions to gain better understanding of the lecture material. | ✓ | ✓ | ✓ | | 1 hour/week |
| Programming Assignment | Students will develop skills implementing selected machine learning algorithms, applying them to small datasets, and interpreting the results. Students can then observe the effectiveness of the algorithm, and evaluate the differences between various algorithms. | | ✓ | ✓ | | |
| Theory Assignment | Students will analyze algorithms theoretically, and derive solutions to various machine learning problems. | | | | ✓ | |
| Course Project | Students will design and create a system based on a machine learning algorithm to solve a real-world problem. Students will report their results in a course report and during a poster session held at the end of the semester. | | ✓ | ✓ | ✓ | |

## 4. Assessment Tasks/Activities (ATs)

*(ATs are designed to assess how well the students achieve the CILOs.)*

| Assessment Tasks/Activities | CILO No. | | | | | Weighting | Remarks |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | |
| Continuous Assessment: 70% | | | | | | | |
| Assignments | | ✓ | ✓ | ✓ | | 30% | |
| Midterm | ✓ | | ✓ | ✓ | | 10% | |
| Course Project^ | | ✓ | ✓ | ✓ | | 30% | |
| Examination^: 30% (duration: 2 hours) | ✓ | | ✓ | ✓ | | 30% | |
| | | | | | | 100% | |

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

## 5. Assessment Rubrics

*(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)*

Applicable to students admitted in Semester A 2022/23 and thereafter

| Assessment Task | Criterion | Excellent (A+, A, A-) | Good (B+, B) | Marginal (B-, C+, C) | Failure (F) |
|---|---|---|---|---|---|
| 1. Assignments | 1.1 ABILITY to APPLY machine learning to problems and INTERPRET the results<br>1.2 ABILITY to COMPARE the accuracy and efficiency of machine learning algorithms<br>1.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate to Basic | Not even reaching marginal levels |
| 2. Midterm | 2.1 ABILITY to EXPLAIN machine learning algorithms, and INTERPRET results from machine learning algorithms<br>2.2 ABILITY to EVALUATE, COMPARE, and CONTRAST different machine learning approaches<br>2.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate to Basic | Not even reaching marginal levels |
| 3. Course Project | 3.1 ABILITY to APPLY machine learning to real-world problems and INTERPRET the results<br>3.2 ABILITY to EVALUATE, COMPARE, and CONTRAST different machine learning algorithms<br>3.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate to Basic | Not even reaching marginal levels |
| 4. Examination | 4.1 ABILITY to EXPLAIN machine learning algorithms, and INTERPRET results from machine learning algorithms<br>4.2 ABILITY to EVALUATE, COMPARE, and CONTRAST different machine learning approaches<br>4.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate to Basic | Not even reaching marginal levels |

Applicable to students admitted before Semester A 2022/23

| Assessment Task | Criterion | Excellent (A+, A, A-) | Good (B+, B, B-) | Fair (C+, C, C-) | Marginal (D) | Failure (F) |
|---|---|---|---|---|---|---|
| 1. Assignments | 1.1 ABILITY to APPLY machine learning to problems and INTERPRET the results<br>1.2 ABILITY to COMPARE the accuracy and efficiency of machine learning algorithms<br>1.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate | Basic | Not even reaching marginal levels |
| 2. Midterm | 2.1 ABILITY to EXPLAIN machine learning algorithms, and INTERPRET results from machine learning algorithms<br>2.2 ABILITY to EVALUATE, COMPARE, and CONTRAST different machine learning approaches<br>2.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate | Basic | Not even reaching marginal levels |
| 3. Course Project | 3.1 ABILITY to APPLY machine learning to real-world problems and INTERPRET the results<br>3.2 ABILITY to EVALUATE, COMPARE, and CONTRAST different machine learning algorithms<br>3.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate | Basic | Not even reaching marginal levels |
| 4. Examination | 4.1 ABILITY to EXPLAIN machine learning algorithms, and INTERPRET results from machine learning algorithms<br>4.2 ABILITY to EVALUATE, COMPARE, and CONTRAST different machine learning approaches<br>4.3 ABILITY to DESIGN and DERIVE new machine learning algorithms | High | Significant | Moderate | Basic | Not even reaching marginal levels |

**Part III Other Information** (more details can be provided separately in the teaching plan)

**1. Keyword Syllabus**

*(An indication of the key topics of the course.)*

The course will mainly focus on fundamental knowledge of designing and deriving machine learning algorithms from first principles. Topics include statistical learning, data clustering, dimensionality reduction and data visualization, discriminative classifiers, and regression. Programming assignments will touch the following applications: document analysis, spam detection, document clustering, image segmentation, data visualization, face detection, face recognition.

Syllabus:

1. Overview of machine learning with real-world examples
2. Statistical learning
    a. probability distributions (univariate)
    b. parameter estimation (maximum likelihood)
    c. Bayes' rule & MAP classifiers
    d. Naive Bayes classifier
    e. multivariate probability distributions
    f. Bayesian classifiers
    g. exponential family distributions & conjugate priors
3. Data clustering
    a. K-means clustering
    b. Gaussian mixture models and the EM algorithm
    c. KDE and mean-shift clustering
    d. Spectral clustering, normalized cuts
4. Dimensionality reduction and visualization
    a. subspace methods: unsupervised (PCA, LSA); supervised (LDA)
    b. non-linear manifold embedding (LLE, MDS, ISOMAP)
    c. Nystrom extension
    d. exponential family PCA and pLSA
5. Discriminative classifiers
    a. nearest neighbors
    b. linear classifiers
        i. Fisher linear discriminant (LDA)
        ii. logistic regression, conditional LL
        iii. linear SVM
    c. non-linear classifiers
        i. kernel SVM
        ii. Boosting
    d. kernel PCA, kernel K-means, and kernel machines
6. Regression
    a. least-squares regression
    b. generalized linear models
    c. Bayesian regression & Gaussian processes

## 2. Reading List

### 2.1 Compulsory Readings

*(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)*

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|---|---|
| 1. | Bishop, *"Pattern Recognition and Machine Learning"*, Springer-Verlag New York, 2006. |

### 2.2 Additional Readings

*(Additional references for students to learn to expand their knowledge about the subject.)*

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|---|---|
| 1. | Murphy, "*Machine Learning: A Probabilistic Perspective*", The MIT Press, 2012. |
| 2. | Schölkopf and Smola, *"Learning with kernels: support vector machines, regularization, optimization, and Beyond."*, The MIT Press, 2001. |
| 3. | Rasmussen and Williams, *"Gaussian Processes for Machine Learning"*, The MIT Press, 2006. |
| 4. | Duda, Hart, & Stork, "Pattern Classification", Wiley-Interscience; 2 edition, 2000. |