City University of Hong Kong
Course Syllabus

offered by College/School/Department of Mathematics
with effect from Semester B 2024 /25

Part I Course Overview

Course Title:	**Reinforcement Learning and Its Applications in Finance**
Course Code:	**MA6634**
Course Duration:	**One Semester**
Credit Units:	**3 CUs**
Level:	**P6**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**Nil**
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

This course introduces fundamental mathematical methods for reinforcement learning and its application in financial problems. It helps students to understand the basic concepts and programming tools in reinforcement learning models and develops students' ability to apply the technique to financial applications.

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.	Explain fundamental concepts and theories of reinforcement learning models include action space, state space, reward, value function, Finite Markov decision processes, policy, and Bellman equation.	30%	✓	✓	
2.	Apply classical dynamic programming and reinforcement learning algorithms, include policy iteration, Q learning, policy gradient methods, and deep Q learning.	25%	✓	✓	
3.	Program the reinforcement learning algorithms.	20%	✓	✓	✓
4.	Implement the models in financial applications	25%	✓	✓	
		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 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.

3. Learning and Teaching Activities (LTAs)

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

LTA	Brief Description	CILO No.						Hours/week (if applicable)
		1	2	3	4			
Lectures	Students learn the primary knowledge through the lectures.	✓	✓	✓	✓			3 hours/week
Assignments	Students review the basic concepts and implement advanced theory for better understanding through take-home assignments.	✓	✓	✓	✓			after-class
Project	In the project, students apply reinforcement learning models to more complex financial problems and implement computing techniques introduced in this course.		✓	✓	✓			after-class

4. Assessment Tasks/Activities (ATs)

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

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

Assessment Tasks/Activities	CILO No.						Weighting	Remarks
	1	2	3	4				
Continuous Assessment: 40%								
Hand-in assignments	✓	✓	✓	✓			20%	
Project		✓	✓	✓			20%	
Examination: 60% (duration: 2 hrs)								
Examination	✓	✓	✓	✓			60%	
							100%	

5. Assessment Rubrics

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

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Hand-in assignments	1.1 Comprehensive understanding of the mathematical concept in Markov decision processes and reinforcement learning.	Consistently demonstrates a thorough understanding of the Markov decision processes and reinforcement learning and has strong ability to solve complex problems	Adequately demonstrates an understanding of the Markov decision processes and reinforcement learning and has ability to solve complex problems	Demonstrates some understanding of the Markov decision processes and reinforcement learning and has some ability to solve simple problems	Demonstrates limited understanding of the Markov decision processes and reinforcement learning and has limited ability to solve simple problems	Demonstrates little understanding of the Markov decision processes and reinforcement learning and is unable to solve relevant problems
	1.2 Ability to apply appropriate algorithms to solve MDP control problems.	Consistently demonstrates a thorough understanding of reinforcement learning and has strong	Adequately demonstrates an understanding of reinforcement learning and has ability to solve MDP control problems	Demonstrates some understanding of reinforcement learning and has some ability to solve MDP control problems	Demonstrates limited understanding of reinforcement learning and has limited ability to solve	Demonstrates little understanding of reinforcement learning and is unable to solve MDP control problems

		ability to solve MDP control problems			MDP control problems problems	
	1.3 Ability to relate reinforcement learning to financial applications.	Consistently demonstrates a thorough understanding of reinforcement learning and has strong ability to solve financial problems	Adequately demonstrates an understanding of reinforcement learning and has ability to solve financial problems	Demonstrates some understanding of reinforcement learning and has some ability to solve financial problems	Demonstrates limited understanding of reinforcement learning and has limited ability to solve financial problems	Demonstrates little understanding of reinforcement learning and is unable to solve financial problems
2. Project	2.1 Ability to apply the reinforcement learning algorithms covered in the course in financial applications.	Demonstrates a comprehensive understanding of reinforcement learning algorithms and strong ability in applying program language to solve financial	Adequately demonstrates an understanding of reinforcement learning algorithms and ability in applying program language to solve financial problems	Demonstrates some understanding of reinforcement learning algorithms and little ability in applying program language to solve financial problems	Demonstrates some understanding of reinforcement learning algorithms but cannot apply program language to solve financial problems	Inappropriately or unable to apply reinforcement learning algorithms to solve problems by programming

		problems				
	2.2 Ability to program and train a simple reinforcement learning model.	Demonstrates a comprehensive understanding of reinforcement learning algorithms and strong ability in applying program language to solve financial problems	Adequately demonstrates an understanding of reinforcement learning algorithms and ability in applying program language to solve financial problems	Demonstrates some understanding of reinforcement learning algorithms and little ability in applying program language to solve financial problems	Demonstrates some understanding of reinforcement learning algorithms but cannot apply program language to solve financial problems	Inappropriately or unable to apply reinforcement learning model to solve problems by programming
	2.3 Ability to discuss and validate the results with data.	Demonstrates a comprehensive understanding of reinforcement learning algorithms and strong ability to evaluate and validate the	Adequately demonstrates an understanding of reinforcement learning algorithms and ability to evaluate and validate the results with data	Demonstrates some understanding of reinforcement learning algorithms and some ability to evaluate and validate the results with data	Demonstrates limited understanding of reinforcement learning algorithms and limited ability to evaluate and validate the results with	Inappropriately or unable to evaluate and validate the results with data

		results with data			data	
3. Examinations	3.1 Understanding of the fundamental concepts, principles, and their application scenarios.	Consistently demonstrates a thorough understanding of the concepts, principles, and applications of reinforcement learning	Adequately demonstrates an understanding of the concepts, principles, and applications of reinforcement learning	Demonstrates some understanding of the concepts, principles, and applications of reinforcement learning	Demonstrates limited understanding of the concepts, principles, and applications of reinforcement learning	Demonstrates little understanding of the concepts, principles, and applications of reinforcement learning
	3.2 Ability to implement the dynamic programming and reinforcement learning algorithms covered in the course.	Consistently demonstrates a thorough understanding of dynamic programming and reinforcement learning algorithms and has strong ability to solve complex problems	Adequately demonstrates an understanding of dynamic programming and reinforcement learning algorithms and has ability to solve complex problems	Demonstrates some understanding of dynamic programming and reinforcement learning algorithms and has some ability to solve simple problems	Demonstrates limited understanding of dynamic programming and reinforcement learning algorithms and has limited ability to solve simple problems	Demonstrates little understanding of dynamic programming and reinforcement learning algorithms and is unable to solve relevant problems

	3.3 Comprehensive problem-solving skills in financial applications underlying dynamic programming and reinforcement learning model.	Consistently demonstrates a thorough understanding of dynamic programming and reinforcement learning model and can always apply them to solve financial problems	Adequately demonstrates an understanding of dynamic programming and reinforcement learning model and can usually apply them to solve financial problems	Demonstrates some understanding of dynamic programming and reinforcement learning model and can sometimes apply them to solve simple financial problems	Demonstrates limited understanding of dynamic programming and reinforcement learning model and can seldom apply them to solve simple financial problems	Demonstrates little understanding of dynamic programming and reinforcement learning model and can rarely or never apply them to solve relevant problems

Applicable to students admitted from Semester A 2022/23 to Summer Term 2024

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Hand-in assignments	1.1 Comprehensive understanding of the mathematical concept in Markov decision processes and reinforcement learning.	Consistently demonstrates a thorough understanding of the Markov decision processes and reinforcement learning and has strong ability to solve complex problems	Adequately demonstrates an understanding of the Markov decision processes and reinforcement learning and has ability to solve complex problems	Demonstrates some understanding of the Markov decision processes and reinforcement learning and has limited ability to solve simple problems	Demonstrates little understanding of the Markov decision processes and reinforcement learning and is unable to solve relevant problems
	1.2 Ability to apply appropriate algorithms to solve MDP control problems.	Consistently demonstrates a thorough understanding of reinforcement learning and has strong ability to solve MDP control problems	Adequately demonstrates an understanding of reinforcement learning and has ability to solve MDP control problems	Demonstrates some understanding of reinforcement learning and has limited ability to solve MDP control problems	Demonstrates little understanding of reinforcement learning and is unable to solve MDP control problems
	1.3 Ability to relate reinforcement learning to financial applications.	Consistently demonstrates a thorough understanding of	Adequately demonstrates an understanding of reinforcement	Demonstrates some understanding of reinforcement learning and has	Demonstrates little understanding of reinforcement learning and is

		reinforcement learning and has strong ability to solve financial problems	learning and has ability to solve financial problems	limited ability to solve financial problems	unable to solve financial problems
2. Project	2.1 Ability to apply the reinforcement learning algorithms covered in the course in financial applications.	Demonstrates a comprehensive understanding of reinforcement learning algorithms and strong ability in applying program language to solve financial problems	Adequately demonstrates an understanding of reinforcement learning algorithms and ability in applying program language to solve financial problems	Demonstrates some understanding of reinforcement learning algorithms and little ability in applying program language to solve financial problems	Inappropriately or unable to apply reinforcement learning algorithms to solve problems by programming
	2.2 Ability to program and train a simple reinforcement learning model.	Demonstrates a comprehensive understanding of reinforcement learning algorithms and strong ability in applying program language to solve financial problems	Adequately demonstrates an understanding of reinforcement learning algorithms and ability in applying program language to solve financial problems	Demonstrates some understanding of reinforcement learning algorithms and little ability in applying program language to solve financial problems	Inappropriately or unable to apply reinforcement learning model to solve problems by programming
	2.3 Ability to discuss and validate the results with data.	Demonstrates a comprehensive understanding of reinforcement	Adequately demonstrates an understanding of reinforcement	Demonstrates some understanding of reinforcement learning algorithms	Inappropriately or unable to evaluate and validate the results with data

		learning algorithms and strong ability to evaluate and validate the results with data	learning algorithms and ability to evaluate and validate the results with data	and limited ability to evaluate and validate the results with data	
3. Examinations	3.1 Understanding of the fundamental concepts, principles, and their application scenarios.	Consistently demonstrates a thorough understanding of the concepts, principles, and applications of reinforcement learning	Adequately demonstrates an understanding of the concepts, principles, and applications of reinforcement learning	Demonstrates some understanding of the concepts, principles, and applications of reinforcement learning	Demonstrates little understanding of the concepts, principles, and applications of reinforcement learning
	3.2 Ability to implement the dynamic programming and reinforcement learning algorithms covered in the course.	Consistently demonstrates a thorough understanding of dynamic programming and reinforcement learning algorithms and has strong ability to solve complex problems	Adequately demonstrates an understanding of dynamic programming and reinforcement learning algorithms and has ability to solve complex problems	Demonstrates some understanding of dynamic programming and reinforcement learning algorithms and has limited ability to solve simple problems	Demonstrates little understanding of dynamic programming and reinforcement learning algorithms and is unable to solve relevant problems
	3.3 Comprehensive problem-solving skills in financial applications underlying dynamic programming and reinforcement learning	Consistently demonstrates a	Adequately demonstrates an	Demonstrates some understanding of	Demonstrates little understanding of

	model.	thorough understanding of dynamic programming and reinforcement learning model and can always apply them to solve financial problems	understanding of dynamic programming and reinforcement learning model and can usually apply them to solve financial problems	dynamic programming and reinforcement learning model and can sometimes apply them to solve simple financial problems	dynamic programming and reinforcement learning model and can rarely or never apply them to solve relevant problems

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.)

Markov Decision Processes. Bellman equation. Dynamic Programming. Q learning and Deep Q learning, Policy gradient methods. Dynamic Asset-Allocation. Optimal Exercise of American Options

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.)

1.	Course materials provided
2.	
3.	
…	

2.2 Additional Readings

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

1.	Reinforcement Learning : An Introduction, Sutton & Barto 1st Edition
2.	Foundations of Reinforcement Learning with Applications in Finance, Ashwin Rao & Tikhon Jelvis 1st Edition
3.	
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