REINFORCEMENT LEARNING IN DIGITAL FINANCE

Course syllabus

MSCA Digital Finance
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DIGITAL

UNIVERSITY OF TWENTE.

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Course manual Reinforcement Learning in Digital Finance

Content

1. Meet the teaching team

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2. General course description

The course 'Reinforcement Learning in Digital Finance' introduces doctoral candidates to the main concepts and techniques of reinforcement learning. The focus lies on applications in digital finance, i.e., optimizing investment portfolios or managing capital in finance markets, requiring strategies that maximize returns while navigating uncertainties. Solving such complex financial problems is crucial for professionals in digital finance and financial engineering. Reinforcement learning has emerged as a powerful solution method for these dynamic resource allocation challenges, making it a key area of study for those interested in modern financial technologies.

The primary objective of this course is to provide an introduction to reinforcement learning, offering a generic introduction of core techniques with a focus on their applications in digital finance. By the end of the course, candidates will have a global understanding of reinforcement learning techniques and their application in digital finance. They will be equipped to formally describe allocation problems, select, and apply appropriate reinforcement learning algorithms within this domain.

To achieve the learning objectives, the course combines lectures, a group project, and a short paper describing the project. The lectures will cover the theoretical foundations of reinforcement learning, various types of algorithms, modeling techniques, and applications in finance. While the focus will be on the basics of reinforcement learning, the course will also introduce more advanced techniques, such as deep neural networks and multi-agent systems. Demonstration models and industry cases will be provided in a tutorial setting, allowing students to experiment and apply these techniques to real-world financial scenarios.

3. Prior knowledge

Doctoral candidates participating in this course are expected to have a basic understanding of stochastic models in particular (partially observable) Markov Decision Processes. Furthermore, a certain degree of familiarity with programming (the course will use Python), dynamic programming, calculus and statistics is expected. Candidates not meeting all prior knowledge requirements can still successfully complete the course, but are expected to put more effort to put into self study.

4. Learning objectives

This course addresses 10 learning objectives. By the end of this course, the doctoral candidate will be able to:

1. Explain the core concepts of reinforcement learning, the computational challenges it tackles and the potential applications;
2. Formulate typical dynamic resource allocation problems in finance as a (partially observable) Markov Decision Process model;
3. Extract appropriate features from real-world financial data;
4. Model and apply basic value- and policy function algorithms;
5. Explain the relevant tunable parameters that determine learning performance, including features and learning-, exploration- and discount rates;
6. Apply neural network applications in the context of (deep) reinforcement learning, as well as other contemporary developments in the domain;
7. Solve classical reinforcement learning problems with the use of neural networks;
8. Transfer classical finance problems to the context of deep reinforcement learning;
9. Apply reinforcement learning principles in the broader context of digital finance, starting with retrieving raw financial data and concluding with comprehensible managerial insights;
10. Explain and present design choices and business implications to both team members and external stakeholders.

5. Study materials

Course materials will be made available via Moodle. The lecture slides form the basis for the written exam, the other materials serve to solidify your understanding of the topics. As a textbook, Sutton & Barto (2018, freely available online) is used.

- Lecture slides and materials provided during the lecture
- Reinforcement Learning: An Introduction (Sutton & Barto, 2018)
- Selected papers, to be provided via Moodle

6. Course setup

6.1 ACTIVITY OVERVIEWS

The activity overview below is indicative and may be subject to changes. Please refer to the course's Moodle page for the most up-to-date timetable.

Date	Time	Instruction mode	Topic	Teacher(s)
02-02-2025	9:00-10:30	Lecture	Course introduction and general introduction to Reinforcement Learning	Wouter van Heeswijk, Jörg Osterrieder, Martijn Mes
02-02-2025	11:00-12:00	Lecture	Reinforcement Learning in Digital Finance	Jörg Osterrieder
02-02-2025	13:00-14:00	Lecture	Markov Decision processes and basics of Q-learning	Wouter van Heeswijk
02-02-2025	14:00-15:00	Tutorial	Q-learning in Taxi Cab environment	Wouter van Heeswijk
02-02-2025	15:15-17:30	Project	Group formation, project selection and problem formulation	Wouter van Heeswijk, Jörg Osterrieder
03-02-2025	9:00-10:30	Lecture	Deep Reinforcement Learning in finance	Jörg Osterrieder
03-02-2025	11:00-12:00	Tutorial	Deep Q-learning for automated stock trading	Jörg Osterrieder, Wouter van Heeswijk
03-02-2025	13:00-15:00	Lecture	Introduction to policy-based reinforcement learning	Wouter van Heeswijk
03-02-2025	15:15-17:30	Project	Project description and coding	Jörg Osterrieder, Wouter van Heeswijk
		Lecture (online)	Guest lectures from industrial partners	
		Meeting (online)	Monthly progress meetings on project	

30-05-2024	Presentation session (online)	Final group presentations

6.2 ASSESSMENT

Candidates are assessed based on the group project in a pass/fail setting, with the evaluation encompassing the quality of the Python code, the final presentation and the paper. The project can be made in groups of 4-5 people. In case of an insufficient project evaluation, a single repair opportunity is provided.

6.3 PROJECT DUE DATES

The due dates for the project are as follows:

Due dates	Assignment	Content
02-02-2025	Project topic and group formation	Choose a project and form a group
30-05-2025	Jupyter notebook - Functioning RL algorithm - Experimental results - Key conclusions Final presentation slides Short paper	20 minute presentation +10 minutes Q&A [hand in presentation slides] Jupyter notebook Short paper

All project files need to be handed in via Moodle before 30-05-2025.

In case project quality is insufficient upon final submission, repair opportunities will be discussed individually. High-quality projects may receive support beyond the course deadlines to transform the group work into an academic paper.

6.3 LECTURES AND PRACTICALS FORMAT

The lectures and tutorials will be held in a hybrid setting; candidates are encouraged to physically attend the training week. Project progress meetings and final presentations will be held online.

1. **Lectures and tutorials**
   Lectures and tutorials will be organized in a hybrid setting during the training week. Supplementary guest lectures may be offered online.
2. **Project progress meetings**
   Project progress meetings will be held online monthly. You will meet with the teachers to present your progress and discuss open questions.
3. **Office hours**
   Office hours for organizational-, project or technical questions may be scheduled on demand and will be held online.
4. **Final presentation**
   The final project presentations will be held online.

6.4 AI AND GROUP CONTRIBUTION RULES

For all group assignments and presentations, it holds that you should hand in/present your own and original work. You have to add an “author contribution & use of AI statement” to the group assignment.

The author contribution statement should include who did what (tasks) and what was the relative contribution of each group member to the overall contribution (percentage). Also, all group members should explicitly agree on the final version of the assignment.

Example author contribution statement:

** Name group member 1: Wrote the introduction of the report, produced the mathematical model of Module 1, downloaded and cleaned the data, produced output statistics and wrote answers 1.1 and 2.3. She debugged the Python code to make the mathematical program work. She read the final version of the report and made final edits. [20%]*

** Name group member 2: … [30%]*

Example of AI statement:

** We declare that no content produced by AI technology has been presented as our own work (both in reporting and coding)*

** We declare that we used that we used ChatGPT 3.5 to improve writing at the sentence level and to better express transitions between paragraphs.*

** We declare that ChatGPT 3.5 has been used to generate initial code snippets and to generate docstrings for functions.*

Note: An extra oral assessment may be part of each assignment as a verification of the authenticity and contribution. Such an oral assessment could also be randomly assigned to a group.