# DEEP REINFORCEMENT LEARNING FOR OPTIMAL PORTFOLIO MANAGEMENT

*The Timeline*

# Dates

- 14th May: Preliminary Report
- 5th July: Individual Meeting 1
- 26th July: Group Meeting 4
- 16th August: Individual Meeting 2
- 3rd September: Report Submission
- 6th September: Video Presentation

# *Now – 14th May: Preliminary Report*

- Chapter 1: Introduction - Aims, objectives, background, motivations, technical specifications, and outline of methodologies.
- Overview of requirements, minimum goals to accomplish
- Chapter 2: Background and Literature Review
  - *Overview of topic area, key concepts and relevant research*
  - *Description of previous work done in related areas,*
  - *Outline of existing methods/approaches proposed by others handling similar problems.*
  - *Constructive criticism on the existing methods/approaches*
- Project Schedule (*Gantt chart*)
  - *Data acquisition*
  - *Implementation*
  - *Analysis and evaluation*

| | Paper | Date | Status | Code | Comments | Algorithms | Author |
|---|---|---|---|---|---|---|---|
| 2 | A Deep Deterministic Policy Gradient-based Strategy for Stocks Portfolio Management | Mar 2021 | | | | DDPG | H Zhang and Z Jiang |
| 3 | Deep Reinforcement Learning with Function Properties in Mean Reversion Strategies | 2021 | | | | PPO, OpenAI gym, Mean reversion | Sophia Gu |
| 4 | DRL for Portfolio Management based on the empirical study of Chinese Stock Market | 2021 | | | | DDPG, Arbitrage Pricing Theory, shorting, CNN | Gang Huang |
| 5 | Deep Reinforcement Learning for Automated Stock Trading: An Ensemble Strategy | 2020 | | FinRL | | Ensemble - PPO, A2C, DDPG | Hongyang Yang |
| 6 | Application of Deep Q-Network in Portfolio Management | 2020 | | | | DD-DQN | Ziming Gao and Z Jiang |
| 7 | Deep Reinforcement Learning for Trading | Nov 2019 | | | | Futures Contracts - DQN, PG, A2C | Zhang |
| 8 | A deep Q-learning portfolio management framework for the cryptocurrency market | Nov 2019 | | | | DQN, D-DQN, DD-DQN | Lucarelli |
| 9 | A deep reinforcement learning approach for automated cryptocurrency trading | May 2019 | | | | | Lucarelli |
| 10 | Reinforcement Learning For Automated Trading | 2019 | | | | GPOMDP (Monte Carlo), PGPE | Necchi |
| 11 | Reinforcement Learning for Portfolio Management | 2019 | | | | DSRQN, REINFORCE, MSM | Filos |
| 12 | Model-based deep reinforcement learning for dynamic portfolio optimization | Jan 2019 | | | | Model based - IPM, gen adv DAN, BCM | Yu |
| 13 | Portfolio Management Based on DDPG Algorithm of Deep Reinforcement Learning | 2018 | ???? | | | | Qi |
| 14 | Practical Deep Reinforcement Learning Approach for Stock Trading | Dec, 2018 | | FinRL | | DDPG | Xiong |
| 15 | Adversarial Deep Reinforcement Learning in Portfolio Management | Nov, 2018 | | Github | | DDPG, PPO, PG | Z Liang |
| 16 | Financial Trading as a Game: A Deep Reinforcement Learning Approach | Jul 2018 | | | | DRQN | CY Huang |
| 17 | Market Self-Learning of Signals, Impact and Optimal Trading | May 2018 | | | | Dynamic Portfolio Optimization, bounded rational agent, IRL | Halperin |
| 18 | MACHINE LEARNING FOR TRADING | Dec 2017 | | | | Q learning | Gordon Ritter |
| 19 | A Deep RL Framework for the Financial Portfolio Management Problem | Jul 2017 | | Github | 12 Crypto asset portfolio | EIIE | Z Jiang |
| 20 | Cryptocurrency portfolio management with deep reinforcement learning | May 2017 | | | | DPG | Z Jiang |
| 21 | Multi-Period Trading via Convex Optimization | Apr 2017 | | | | | Boyd |
| 22 | Deep Direct Reinforcement Learning for Financial Signal Representation and Trading | 2016 | | | Solves without price prediction, Single asset movement | | Deng |
| 23 | Portfolio Management using Reinforcement Learning | 2016 | | | Basic implementation of DQN | 2 stock DQN learner | Jin |
| 24 | An Investigation into the Use of RL Techniques within the Algorithmic Trading Domain | 2015 | | | Solves without price prediction | Dissertation - LSTD for forex trading | Cumming |
| 25 | An automated FX trading system using adaptive reinforcement learning | 2006 | | | Solves without price prediction, Single asset movement | | Dempster |
| 26 | Learning to Trade via Direct Reinforcement | 2001 | | | Solves without price prediction, Single asset movement | | Moody |
| 27 | An Algorithm for Trading and Portfolio Management using Q-Learning and Sharpe Ratio | 2000 | | | | Novel local & global agents for learning behaviour and reward | Gao |
| 28 | Reinforcement Learning for Trading Systems and Portfolios | 1998 | | | | | Moody |
| 29 | Performance Functions and Reinforcement Learning for Trading systems and Portfolios | 1997 | | | | | Moody |
| 30 | **SURVEYS** | | | | | | |
| 31 | Reinforcement learning in financial markets - a survey | Dec 2018 | | | | | |
| 32 | Model-Free Reinforcement Learning for Financial Portfolios: A Brief Survey | May 2019 | | | | | |
| 33 | Comprehensive Review of Deep Reinforcement Learning Methods and Applications in E | 2020 | | | | | |
| 34 | Continuous versus discrete action spaces for deep reinforcement learning | | | | | | |
| 35 | Modern Perspectives on Reinforcement Learning in Finance | Jan 2019 | | | | | Gordon Ritter |

*14th May – 3rd June*

# EXAMS

# *3rd June – 5th July: Individual Meeting 1*

- Implement simple versions of DQN and DDPG algorithms on arbitrary tasks
  - *Finalize tools and frameworks to use*
  - *Develop a taste for designing environments in OpenAI Gym*
- Finalize dataset to be used
- Begin environment design for portfolio allocation
  - *Feature Engineering*
  - *Data Normalization*
- Develop Python scripts for evaluation of metrics and against baselines
- Begin Chapter 3: Methodology

| **Starting point for beginners** | | | | **Tutorials** | **RL for Portfolio Management** | | | |
|---|---|---|---|---|---|---|---|---|
| OpenAI Spinning Up | GitHub | TF, Torch | | Pytorch DQN | FinRL: A Deep Reinforcement Learning Library for Automated Stock Trading in Quantitative Finance | . | GitHub | |
| Udacity Deep RL repo | GitHub | Torch | | Keras RL | | | | |
| Denny Britz Github | GitHub | TF | | Stable Baselines 3 | | | | |
| | | | | OpenAI Gym | | | | |
| **Advanced implementations** | | | | FinRL: Portfolio Allocation | | | | |
| OpenAI Baselines | | TF | | FinRL: Blog post | | | | |
| Stable Baselines | | TF | | | | | | |
| Stable Baselines3 | Used by FinRL https://araffin.github.io/post/sb3 | Torch | | | **Implementations inspired by "*A Deep Reinforcement Learning Framework for the Financial Portfolio Management Problem*"** | | **Data** | **Range** |
| | | | | | https://github.com/liangzp/Reinforcement-learning-in-portfolio-manag | . | Chinese, American Stock Prices | 2015-17 |
| RLLib | GitHub | TF, Torch | | | https://github.com/wassname/rl-portfolio-management | | OHLCV for 14 cryptocurrencies | 2015-17 |
| Garage | | TF, Torch | | | https://github.com/selimamrouni/Deep-Portfolio-Management-Reinfo | . | 5yr Stock Prices | 2013-18 |
| TRFL | Deepmind - Building blocks, mathematical operations for RL Agents | TF | | | https://github.com/vermouth1992/drl-portfolio-management | | 5yr S&P 500 prices | 2013-18 |
| **(incomplete)** | | | | | | | Datamodel | |
| Acme | Deepmind | TF | | | https://github.com/aws/amazon-sagemaker-examples/tree/master/re | . | | |
| Dopamine | Google | TF | | | | | | |
| ReAgent | Facebook | Torch | | | | | | |
| Tensorforce | | TF | | | | | | |
| RLkit | | Torch | | | | | | |
| DeeR | | Keras | | | | | | |
| Sagemaker | Amazon | TF, Torch | | | | | | |

## *Data*

- S&P 500 stock prices (2013 – 18)
- 14 popular cryptocurrencies (2015 – 17)
- Stanford dataset for Finance and Portfolio Optimization (2006 – 16)
  - *52 popular ETFs*

- FinRL API to download stock market data
  - *NASDAQ 100, DJIA, S&P 500, HSI, SSE 50, CSI 300, etc.*

## *5th July – 26th July: Group Meeting 4*

- Train, (Back)Test, Analyse and Improve, Repeat
- Document performance and results
- Begin Chapter 4: Evaluation and Results
- (Hopefully freeze development by this meeting)

## *26th July – 16th August: Individual Meeting 2*

- Concentrate of completion of report and begin Chapter 5: Discussion
- Fine tune agents (if needed)

## *16th August – 3rd September*

- Make sure everything is submitted.

*FIN*