

# Reinforcement Learning Project

## What you need to do

Apply reinforcement learning methods to solve a problem of your choice. You may choose any problem that engages your interest, but its state or action space must be large enough so that tabular reinforcement learning methods cannot be used to solve it effectively.

Some problems that have been tackled in past projects include:

- playing Atari arcade games,
- teaching a four-legged creature how to walk,
- teaching a simulated bipedal robot how to navigate an obstacle course,
- driving a simulated car around a racetrack,
- playing Super Mario Bros.,
- landing a simulated spacecraft on the moon, and
- swinging-up a simulated double pendulum.

Your objective is to solve your chosen problem to the best of your ability. You are allowed to use any reinforcement learning method, and are not limited to methods that we have explicitly covered in the unit.

You should work in groups of **four** students, however, we will consider groups of three or five if there is a strong justification. You will have the option of forming your groups on your own; otherwise, you will be assigned to a group randomly. Multiple groups are allowed to work on the same problem.

## Deliverables

The project has two parts. First, you will present your progress to date towards the end of the semester. At a later date, you will submit the finished project on Moodle.

### Part 1 - 10% of the Marks

- Presentation of your progress to date (in-person presentation on campus), and
- presentation slides.

### Part 2 - 90% of the Marks

- Project report,
- video of your agent(s) before and after learning,
- your source code, and
- group contribution form.

## Project report

Your project report *must* be divided into the following sections:

1. **Problem Definition:** A clear, precise, and concise description of your chosen problem, including the states, actions, transition dynamics, and the reward function. You will lose marks for an unclear, incorrect, or incomplete problem definition.
2. **Background:** A discussion of reinforcement learning methods that may be effective at solving your chosen problem, their strengths and weaknesses for your chosen problem, and any existing results in the scientific literature (or publicly available online) on your chosen problem or similar problems.
3. **Method:** A description of the method(s) used to solve your chosen problem, a concise explanation of how these methods work (in your own words), and an explanation of why you chose these specific methods.
4. **Results:** A presentation of your results, showing how quickly and how well your agent(s) learn (i.e. improve their policies). Include informative baselines for comparison (e.g. the best possible performance, the performance of an average human, the performance of an agent that selects actions randomly, etc.).
5. **Discussion:** An evaluation of how well you solved your chosen problem.
6. **Future Work:** A discussion of potential future work you would complete if you had more time.
7. **Personal Experience:** A discussion of your personal experience with the project, such as difficulties or pleasant surprises you encountered while completing it.
8. **References**
9. **Appendices:** Appendices should include (1) a detailed description of the problem domain, including the states, actions, reward function, and transition dynamics; (2) all experimental details so that the reader can fully replicate your experiments; and (3) how you selected your hyperparameters (if applicable).

Your report should be written using the provided LaTeX template, and should be no longer than seven pages including the figures but excluding the references and the appendices. The content of all figures, including any embedded text, should be clearly legible — you will lose marks for figures and text that are too small to view comfortably. Any appendices should be clearly referenced in the main body of your report. All sources should be referenced appropriately. A single report should be submitted by each group.

## Presentation

Your group will be expected to give an in-person presentation during week 11. Your presentation should summarise the work you have been undertaking, the progress you have made and any results you were able to achieve. Somebody should be able to listen to your presentation and leave having a good understanding of your chosen problem, solution method(s), and your results to date. Aside from that, you are free to organise your presentation as you wish. Your presentation should be no longer than five minutes. All group members must take part in the presentation. Exceptions can be made if you have legitimate reasons for not being able to present.

## Video of agent performance

You should submit a video showing your agent's performance before and after training, clearly demonstrating that some learning has occurred. This video should be at most two minutes long (but can be shorter as long as it demonstrates learning), but may be sped up as long as the content remains clear. You should include a link to the video in your report appendices. The link should be publicly accessible for at least 2 months after the submission.

## Source code

You should submit all source code used to complete this project. We should be able to run your code and reproduce your results ourselves if we need to, so it might be wise to include a short README file.

You are free to use third-party libraries for generic functionality and to implement your environment, but you should implement your chosen reinforcement learning method(s) yourself. For example, you are free to use libraries like NumPy, SciPy, Pandas for math operations and Tensorflow or PyTorch to implement neural networks, or use an existing environment from a library like OpenAI Gym, but you should not use a library like OpenAI Baselines to implement an entire reinforcement learning algorithm like DQN.

## Group contribution form

You will be working as part of a group to complete this project. As such, you should ensure that you organise your time and resources effectively: finding time to plan, set expectations, discuss your work, and agree on each group member's responsibilities is essential.

We have provided you with a group contribution form to fill out and submit. To fill out this form, you must agree on the relative contributions of each group member to your final project. We will use these relative contributions to scale marks where appropriate. For more information, please see the provided group contribution form document.

## Deadlines

- Presentation Slides – **Friday 9<sup>th</sup> December, 2022**
- In-Person Presentations – **Week 11 (w/c 12<sup>th</sup> December 2022)**
- Report + Code + Video + Group Contribution Form – **Monday 9<sup>th</sup> January, 2023**

Presentations will be given in person during the labs and lectures during the week 11 on the university timetable. Each group's presentation times will be announced closer to the time, but you will be required to attend and observe your classmate's presentations. We hope this will be a helpful learning experience to see how others have approached their problems.

## Presentation Marking Criteria

Your **presentation** will be marked on the following criteria which will be worth **10%** of the marks:

- **Methodology:** How suitable is your approach to the problem you have selected?

- **Progress:** How much have you been able to achieve so far? Have you started yet? To achieve top marks you must demonstrate significant progress with your agent.
- **Clarity:** How clear and concise is your presentation? Does it adequately convey the difficulty of your problem and the approach you are taking to solve it.
- **Peer Mark:** During your presentation your peers will be asked to fill in a grade sheet about your presentation and how well you answer their questions. Their grades will make up a small portion of your grade for the presentation.

## Report Marking Criteria

Your **report** will be marked on four criteria which will be worth **90%** of the marks:

- **Quality:** How high was the performance of your trained agent relative to the difficulty of the problem that you chose to solve?
- **Rigour:** How thoroughly have you evaluated the performance of your agent?
- **Understanding:** How deep is your understanding of reinforcement learning in general, and of the methods you have implemented in particular? Have you made principled decisions when selecting your chosen solution method over potential alternatives?
- **Presentation:** How clear, concise, and well-organised is your report?

## Marking Criteria

**In order to achieve a grade above 40%**, students must implement an agent that demonstrates a noticeable amount of learning in their chosen domain. At this level, the students' chosen problem may be relatively simple (while still fulfilling the requirements for the project). Students should perform some basic analysis of their agent's performance but may not provide comparisons to useful baselines and alternative methods. Students should demonstrate a basic understanding of the method(s) they chose to implement but may demonstrate only a limited appreciation of possible alternatives. The students' writing style may be weak, with little effort made to ensure correct spelling and grammar. Students may position figures haphazardly and may not discuss them appropriately. The ideas and arguments presented in the report and presentation may be unorganised and unclear.

**In order to achieve a grade above 60%**, students must implement an agent that demonstrates a substantial level of learning in their chosen domain relative to the difficulty of their chosen problem. Students should thoroughly evaluate the performance of their agent(s), and include comparisons with key baselines and some alternative approaches. Students should demonstrate a good understanding of their chosen method(s) and give reasonable justifications for their algorithmic choices. This should include demonstrating a reasonable appreciation of the strengths and weaknesses of alternative methods. Throughout the report, the writing style should be clear, consistent, and correct. Students should use figures effectively to present key information and results, discuss their content appropriately, and put thought into their placement. Students should present key points clearly in both their report and presentation. Their arguments should lead to natural and well-justified conclusions.

**In order to achieve a grade above 70%**, students should implement an agent that demonstrates a high level of performance in their chosen domain, relative to the difficulty of their chosen problem

and the amount of time and compute resources available. In simpler domains, a near-optimal policy may well be learned. The solution methods developed should go beyond the content covered explicitly in the unit. Students should perform an in-depth evaluation of their chosen method(s) and include comparisons to and evaluations of additional baselines and alternative methods. Students may show evidence of creativity in their algorithmic approach and analysis. Students should demonstrate a deep understanding of their chosen method(s), as well as possible alternative approaches. All algorithmic choices should be well justified. The students' writing style should be professional and fluent throughout. Students should use figures effectively and selectively to present key information and results, as well as to complement text where appropriate. The students' report and presentation should be well organised. Ideas and arguments should be conveyed clearly and concisely at an appropriate level of detail.

**Grades above 70% will normally be rare.**

## **Penalties**

All deliverables are mandatory. A penalty of  $-10$  marks will be applied for each deliverable that is missing from your submission.

A penalty of  $-5$  marks will also be applied for each of the following issues: exceeding the specified page or time limits, not using the provided LaTeX template to write the report, not following the prescribed report structure, or not having all group members participate in the presentation (unless permission obtained in advance from unit convenors).

We will not read beyond the first seven pages of the main body of your report, and no marks will be given for content beyond this point. The same applies to your presentation: we will be cutting off your presentation at the end of your five-minute slot, so make sure your presentation does not overrun.

## **Plagiarism**

Please ensure that you develop your solution and write your report independently of other groups. Cite literature appropriately and give clear credit to the authors of any third-party code you use as part of your solution.

Do not plagiarise. Plagiarism is a serious academic offence. Both your source code and report will be checked for evidence of plagiarism. For details on what plagiarism is and how to avoid it, please visit <http://www.bath.ac.uk/library/help/infoguides/plagiarism.html>.