ELEC0144
Machine Learning for Robotics

Assignment 3

Year 2023/2024

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Guidelines:

- **All deadlines are specified in Moodle**, under the assessment section. Penalties will be applied for late submissions in accordance with the guidelines: https://www.ucl.ac.uk/academic-manual/chapters/chapter-4-assessment-framework-taught-programmes/section-3-module-assessment#3.12

- Please also be aware of **UCL's Academic Misconduct policy**: https://www.ucl.ac.uk/academic-manual/chapters/chapter-6-student-casework-framework/section-9-student-academic-misconduct-procedure. Collaboration with other teams via exchange of ideas, sharing of codes, re-using portions of the reports etc. are not allowed and will be considered as collusion.

1 Assignment 3: Q-Learning & Path Planning

1.1 Objective Summary

In the first part of the assignment, you will be required to write your own code to implement tabular Q-Learning to find the optimal path to the goal with the highest reward.

In the second part of the assignment, you will write your own code for Dijkstra and A* algorithms, to find the shortest path to the target location.

Finally, you will write a literature review about latest development in path planning algorithms.

Note: There is no single “right” way to code. As long as your code gives the correct results, and as long as you write sufficient comments to explain how it works, it will be acceptable.

1.2 Task 1: Tabular Q-Learning

You are given a grid-world as shown in Figure 1:

9	10	11	12 (+10)
5	6	7	8 (-10)
1	2	3	4

Figure 1: Grid world

There is a positive reward of +10 if the agent enters cell number 12, and a negative reward of -10 if the agent enters cell number 8. Cell number 6 is an obstacle, which the agent cannot enter. The agent will also be refrained from exiting the grid-world. For e.g. if the agent is in cell number 2, and the action is down, then the agent will still stay in cell number 2.

The agent can only perform 4 actions: Up, Right, Down and Left. It is assumed that there is no slip, thus the agent will execute the command perfectly.

There is a living reward of -1 for each step taken, even if the agent tries (but fails) to exit the grid world or enter the obstacle (cell number 6).

Based on your understanding of the tabular Q-Learning algorithm taught in the lectures, write your own code to implement the algorithm. The results should be the Q-values of all the state-action pair, as well as the best action for each cell.

In your report, please explain the updates of the Q-values for the first three iterations (similar to lecture slides) of the first episode, second episode and third episode.

1.3 Task 2: Dijkstra's Algorithm on 6 x 6 Grid

You are given a 6 x 6 grid as shown in Figure 2.

The starting position is grid number 5, and the target position is grid number 32. The shaded grids (grid 2, 10, 11, 20, 21 and 27) are obstacles. There are 8 possible movements – up, down, left, right, diagonally up-right, diagonally up-left, diagonally down-right, diagonally down-left. The cost to move from one grid to another is 1 if directly horizontal or vertical, and $\sqrt{2}$ if diagonal.

1	2	3	4	5 ▶	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32 ◎	33	34	35	36

Figure 2: 6x6 Grid

Write your code to implement Dijkstra's algorithm,, to find the path with the least cost from grid number 5 to grid number 32. The results of your code should clearly demonstrate:

- The evolution of the "front" set (which should include cost and predecessor) → this should be printed to a txt file, which you should submit with the code and report.
- The evolution of the "visited" set → this should be printed to a txt file, which you should submit with the code and report.
- And finally, the shortest path from grid number 5 to grid number 32.

Next, add one more obstacle at grid 33 (Figure 3).

1	2	3	4	5 ▶	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32 ◎	33	34	35	36

Figure 3: Additional Obstacle

Update your code and show the shortest path from grid number 5 to grid number 32. Also print the "front" set and "visited" set in txt files.

1.4 Task 3: A* Algorithm on 6 x 6 Grid

Using the same grid in Figure 3, write your code to implement A* algorithm, to find the path with the least cost from **grid number 16** to grid number 32. The results of your code should clearly demonstrate:

- The evolution of the "front" set (which should include cost f, g and predecessor) → this should be printed to a txt file, which you should submit with the code and report.
- The evolution of the "visited" set → this should be printed to a txt file, which you should submit with the code and report.
- And finally, the shortest path from **grid number 16** to grid number 32.
- Run your Dijsktra's code from Task 2 with **grid number 16** as the starting position, and compare the results from Dijsktra's and A* algorithms.

1.5 Task 4: Literature Review on Path Planning

Finally, write a two-page literature review about the latest advancements in path planning algorithms. You should not include Dijkstra and A* algorithms which have already been covered in the course. There is no limitation of the year of publication of the algorithms.

1.6 What to Submit

- Your Matlab codes, with proper comments. The code will be tested!
- A written report which details the implementation of Q-Learning, Dijkstra's and A* algorithms, results, comparisons, discussions etc.
- You should **put everything (Matlab codes, txt files AND your written report) into a zip folder**, then submit the zip folder onto the submission point on Moodle. Note: please do not submit .rar file – only .zip is allowed.
- Only one member per team needs to submit the zip folder.

1.7 More about the Report

The report should have a cover page clearly indicating the following details:

- Report title.
- Team number.
- Full name, student number and email address for each team member.
- Submission date.

The body of the report must be organized under the following section headings:

- Executive summary
- Tabular Q-Learning
- Dijkstra's Algorithm on 6 x 6 Grid
- A* Algorithm on 6 x 6 Grid
- Literature Review on Path Planning
- Teamwork – How the tasks have been split among the team members.
- Conclusion

The list of references should appear on separate pages. References should be formatted using the IEEE Citation Style. It is extremely important that all third party sources of information are properly credited and referenced in the correct manner. The inclusion of any text or diagrams from websites or documents must be clearly indicated and referenced.

Font size should be exactly 11 points. Recommended font type is Calibri or Arial. Text should be both left and right aligned (justified text). All figures should have captions, axes labels and legends where appropriate. Curves should be distinguishable even if printed in black and white.

1.8 Marking Criteria

This assignment contributes 30% to the overall score of the module. The marking criteria are described in the following table:

	Criteria	Mark Weight
Q-Learning (Code)	Code works properly, with good comments.	4%
Q-Learning (Report)	Details of the algorithm, derivation, discussions clear and comprehensive. Note: Only first 3 iterations for the first 3 episodes need to be shown to explain the algorithm.	4%
Dijkstra's Algorithm on 6 x 6 Grid (Code)	Code works properly, with good comments.	4%
Dijkstra's Algorithm on 6 x 6 Grid (Report)	Details of the algorithm, derivation, discussions and comparisons clear and comprehensive.	4%
A* Algorithm on 6 x 6 Grid (Code)	Code works properly, with good comments.	4%
A* Algorithm on 6 x 6 Grid (Report)	Details of the algorithm, derivation, discussions and comparisons clear and comprehensive.	4%
Literature Review	Evidence of reading a wide range of literature, clear evidence of critical thinking, good organization.	4%
Report (Format)	English syntax and style, general organization and formatting, figure, table and equation presentation and use, literature citations are use all appropriate.	2%

For each of the categories above, the marking rubric is as follows:

	0-39%	40-49%	50-59%	60-69%	70-79%	80-100%
Codes	Program does not work, or has major flaws that prevent its intended use. Program is very difficult to read. Code contains lines that do not work or are out of order.	Program mostly work, but has major flaws. Program is difficult to read.	Program works in the way the student intended, but has minor flaws. Program is slightly difficult to read.	Program works in the way the student intended. Program is well organized, easy to read and understand.	Program is functional and refined. Program is well organized, makes good use of white space and comments.	Program is functional and exceptionally refined, with extra features that exceed the requirements. Program is extremely well organized, makes good use of white space and comments. Variables have helpful names.

	0-39%	40-49%	50-59%	60-69%	70-79%	80-100%
Report	Missing or very poor written-report.	Details and examples are not organized, are hard to follow and understand. Unable to find specific details.	Information is scattered and needs further development. Details are somewhat sketchy.	Information is logically ordered with paragraphs and transitions. Some details don't support the report topic.	Information is presented in effective order. Good structure of paragraphs and transitions enhances readability and comprehension. Supporting details are specific to topic and provide the necessary information. Good discussions which demonstrates critical thinking and analytical skills.	Information is presented in effective order, and is of award or publication quality. Excellent structure of paragraphs and transitions enhances readability and comprehension. Supporting details are specific to topic and provide the necessary information. Exceptional discussions which demonstrates excellent critical thinking and analytical skills.
Literature	Missing or poor bibliography, e.g. unrelated or irrelevant to project. Missing or Poor literature review.	Basic bibliography with a very limited selection of literature or disproportionat e use of grey literature. Basic or no justifications of choices. Basic literature review, with significant gaps.	Reasonable bibliography with some gaps and limited justifications of choices. Reasonable literature review, with some weaknesses.	Good bibliography covering breadth and/or depth. Good justifications of choices. Sound literature review, with minor gaps.	Very good bibliography covering breadth and depth. Very good justifications of choices. Very critical literature review.	Exceptionally good bibliography covering breadth and depth near the forefront of knowledge. Exceptionally good justifications of choices. Exceptionally critical literature review.

	0-39%	40-49%	50-59%	60-69%	70-79%	80-100%
Format	A (very) large number of language errors. Inappropriate language style. Significant proportion of the report(very) difficult to follow. Literature missing or incorrectly cited, unsuitable formatting, or not accessible, e.g. wrong or broken links, non-English language.	Frequent language errors and/or inconsistent use of language style distract from the content. Citations accessible, but significant formatting errors distract from the content.	Report is generally readable, but with significant number of language errors. Language style requires some reworking. Mostly correct citations and formatting following guidelines, with some errors or inconsistencies.	Report generally well written, using scientific/technical language, but with some language errors. Correct citations and formatting with minor errors or inconsistencies.	Report well written throughout, always using of scientific/technical language. No or only minor language errors. Correct citations and formatting without errors or inconsistencies.	Error free Report, with excellent use of scientific/technical language. Correct citations and formatting without errors or inconsistencies. Citations might be hyperlinked to online version where possible.

1.9 Peer Review

Your group will receive a group mark for this assignment.

Individual students will then receive a different mark based on peer review. In the peer review, you will be assessed by your team members on your attendance, effort, communication, contribution, respect, collaboration and standard of work.

The calculation is as follows:

- Group mark: Numerical score out of 20 (e.g. 15)
- Peer Review: Average percentage given by other students (e.g. 70%)
- Individual mark = Group mark x Peer Review (e.g. 15 x 70% = 10.5)

Note: Peer review submission is **compulsory**. Students who do not submit the peer review will have their individual peer review score capped at 70%.

You will be using the following peer review rubric:

Criteria	**No submission (0%)**	**Poor (40%)**	**Satisfactory (70%)**	**Good (100%)**
Attendance to meetings.	Never turns up to meetings.	Miss several meetings or late to several meetings, without notifying teammates.	Always attend meetings but late for several times. Teammates notified if cannot attend or late (with reasons provided).	Always attend meetings, always punctual. Teammates notified if cannot attend (with reasons provided).

Participation during meetings.	No participation during meetings.	Seldom actively providing suggestions, ideas, comments. Seldom participate in discussions. Seldom respectful to other students' ideas.	Actively providing suggestions, ideas, comments most of the time. Participate in discussions most of the time. Respectful to other students' ideas most of the time.	Always actively providing suggestions, ideas, comments. Always participate in discussions. Always respectful to other students' ideas.
Contribution to project and standard of work.	No contribution to the project.	Minimal contributions, frequently needs help from others.	Works independently but quality is not very high, needs some help with work.	Excellent quality of work, can work independently and able to help others if needed.
Communication	No communication at all.	Huge delay in replying messages / emails. Huge delay in seeking help, thereby delaying progress badly or create huge stress towards deadline.	Slight delay in replying messages / emails. Slight delay in seeking help, thereby delaying progress slightly or create some stress towards deadline.	Keep others up-to-date with the progress. Seek help early on (if needed) so as not to delay the project or create stress towards deadline. Fast in replying messages / emails.