F29AI – Artificial Intelligence and Intelligent Agents

Coursework 1 – Knowledge Representation & Automated Planning

You should complete this coursework **individually**. This coursework is worth **15%** of your overall F29AI mark. Details of what you should do and hand in, and how you will be assessed, are described in this document.

Problem description

The Heriot-Watt SpacePort has decided to launch a next-generation spacecraft for planetary exploration. Operations on board the spacecraft will be controlled by mission plans generated using an automated planner that will direct the people, autonomous agents, and spacecraft's controls. The spacecraft itself is a large ship with multiple sections, including the bridge, launch bay, science lab, engineering, and possibly others. Different types of personnel serve on board the spacecraft: the captain, engineers, science officers, and navigators. The spacecraft has also been equipped with a set of autonomous probes and landers, along with a set of maintenance activity vehicles (MAVs) that personnel can use to perform extravehicular activities (EVAs) outside the spacecraft.

Some of the spacecraft's operations are described in the following list (which isn't exhaustive):

1. The captain can order the spacecraft to travel to a given region of space, provided the captain is on the bridge and a navigator is present to receive the order.
2. The spacecraft can travel to a region of space provided the spacecraft isn't damaged and a navigator is on the bridge to control the spacecraft. The navigator must have received an order to travel to that region.
3. Personnel can move between different sections of the spacecraft, which are connected by doors. Personnel may have to pass through different sections to reach their destination and cannot simply move from any location to any other location directly.
4. If the ship is damaged, an engineer can repair the ship by performing an EVA while inside a MAV. Another engineer must monitor the operation from engineering.
5. Regions of space can be empty or can contain a nebula, an asteroid belt, and/or a planet.
6. A probe can be deployed to collect a sample of plasma from a region of space with a nebula.
7. A probe can be deployed to scan a planet to determine an optimal touchdown location for a lander.
8. Probes, landers, and MAVs can be launched from the launch bay provided an engineer is in the launch bay to operate the launch controls. Probes and MAVs can also be retrieved back into the launch bay if an engineer is present. When a probe is retrieved, any collected plasma is automatically transferred into the launch bay, and any scans taken by the probe are copied into the spacecraft's central computer.
9. Only science officers can move plasma around the ship and study plasma. Plasma studies must take place in the science lab.
10. A lander can land on a planet provided it has a touchdown location. A lander attempting to land without a touchdown location will crash on the planet's surface.
11. A lander can scan a planet if it has successfully landed on the planet.
12. A lander can communicate the results of a planetary scan to the spacecraft provided it deploys a communication antenna. If the planet has a high level of radiation then the lander must deploy two antennae to act as a high-gain antenna array.
13. If the spacecraft enters a region of space with an asteroid belt then the spacecraft becomes damaged, rendering it immobile until repaired. If a probe is deployed in a region of space with an asteroid belt then the probe is destroyed.
14. If a MAV is deployed in a region of space with a nebula then the MAV is disabled due to high levels of ionizing radiation.
15. When the spacecraft returns to Earth, the results of all studies and scans must be communicated back to Mission Control at the SpacePort to successfully end the mission.

At launch, the spacecraft is given a series of missions that it must complete. These missions might include retrieving samples from nebulae and studying these samples, scanning planets for optimal landing sites, and performing full planetary scans. The ship initially starts at Earth and must return to Earth at the successful completion of its missions.

What to do

1) **PDDL implementation:** You must model the spacecraft exploration domain in PDDL by defining the properties, objects, and actions that are needed to describe the domain. Note that the planning domain is described at an abstract level and is somewhat incomplete, with certain pieces of information missing. You must make design decisions as to how you will represent the knowledge and actions necessary to encode this scenario as a planning problem. Some requirements are more difficult than others. It is strongly recommended that you try to implement the domain incrementally, and ensuring that some parts of the domain work correctly before moving on to others. Use the example domains from the PDDL lectures as a starting point for your solutions. You may also find that the planning time increases as you add more complexity. You may have to consider whether an alternative knowledge representation leads to a better solution. You may use the planning tools available at http://editor.planning.domains/, the Fast Forward (FF) planner, or the Fast Downward planner. Feel free to use any other planner you find that supports PDDL but ensure your solution works with one of the planners listed above. Note that the performance of certain planners (e.g., FF and Fast Downward) may outperform that of the web-based planner. Make sure you test your solution on a series of different problem scenarios.

2) **Additional feature:** In addition to the domain described above, design an additional feature in PDDL to add to the domain (e.g., new personnel that can perform some task, a new function for the probe, etc.) that isn't included in the above domain description. Add this feature to your domain and test it.

3) **Report:** Write a short report (maximum 2 pages) outlining your solution, design decisions, layout of the spacecraft/regions of space, and additional feature. The report will be used to help understand your code.

Postgraduate Students Only

In addition to the above instructions, postgraduate students in a 1-year programme should also answer the following questions:

- How well does the domain scale? Choose a planning problem and increase some feature of the domain (e.g., the number of locations to explore, the number of people on the spacecraft, the number of probes, etc.). Does this have an effect on the planning times or the plan length? Does the planner ever fail to generate a plan? Include a brief description of these results in the report (maximum 2 additional pages). Use tables and graphs to illustrate the data you collected. Speculate on the robustness of your domain and how you might improve it to scale to larger problem instances.

What to hand in

- **PDDL source files:** Submit your PDDL source files (domain + problems) in a zip/tar file. Make sure your source files have comments describing the properties and actions you've defined. Your solution should consist of a single PDDL domain file and at least 4 different PDDL problem files illustrating different scenarios that are supported by your domain. One of the problem files must test your additional feature. You should aim for comprehensive scenarios that support multiple missions in each problem file. Your source files will be tested to see if they are operational and checked for plagiarism.

- **Report:** Submit your report as a PDF file. Your report will be checked for plagiarism.

Deadlines

The deadline for submitting Coursework 1 is **Thursday, 31 October 2019**. Submissions are due by **3:30pm (Edinburgh local time)** for the Edinburgh Campus, **5:00pm (Dubai local time)** for undergraduate students at the Dubai Campus, and **11:59pm (Dubai local time)** for postgraduate students at the Dubai Campus.
Submit your coursework on Vision in the **Coursework** section of F29AI.

Assessment

This coursework will count towards **15%** of your overall course mark for F29AI and will be marked out of **20 marks**. You will be assessed on the quality and content of your report, the style of your PDDL code, and the correctness of your solution.

Quality of report and solution (5 marks)

The quality mark will primarily be based on your 2-page written report which will outline your solution, design decisions, and additional domain feature. Your report should be well prepared and presented, with good English usage and grammar, and appropriate visual appearance. Your PDDL code will also be checked and the report will be used to help supplement the code in understanding your overall approach to the problem and the quality of your solution. Usual program quality criteria (e.g., use of whitespace, comments, naming conventions, etc.) will apply here to assess the readability of the code. The marker will be looking to see if you understand how to write PDDL domains and problems and have made good use of the language features that are available.

Postgraduate students only: Reports by postgraduate students may contain an additional 2 pages and should also include details about your scalability/robustness study (including appropriate use of tables and graphs), and appropriate conclusions. Questions concerning planning time/length, robustness, and scalability improvements should be addressed in the report.

0 **None**	**1** **Poor**	**2** **Fair**	**3** **Good**	**4** **Very good**	**5** **Excellent**
No report submitted.	Weak preparation and unstructured report. Weak quality solution. Basic domain features. PDDL code is not understandable. [Postgraduate students: Questions not answered or addressed.]	Adequate preparation and structure of report. Fair quality solution. Mostly basic domain features. PDDL code is very difficult to understand. [Postgraduate students: Basic information provided with few conclusions.]	Thorough preparation and structure of report. A good quality solution overall with a mix of basic and advanced domain features. PDDL code is mainly well written, clear, and understandable. [Postgraduate students: Good description with all required details and appropriate conclusions.]	Very thorough preparation and structure of report, with many design details included. A good mix of domain features, with advanced features enhancing the overall approach. PDDL code is very well written, completely clear and understandable. [Postgraduate students: Very good description with all required details & strong conclusions.]	Exceptional preparation and structure of report. Excellent design designs and use of advanced features which enhance the overall approach. PDDL code is excellent, with all aspects of the code easily understandable. [Postgraduate students: Excellent content, data, and conclusions.]

Correctness of solution (15 marks)

The correctness mark will primarily be based on the PDDL code you have supplied and how correctly it implements the coursework specification. You may submit a single PDDL domain file and multiple PDDL problem files in a single zip/tar file. The supplied files should provide coverage of the various scenario requirements and demonstrate correct behaviour. The marker will test a selection of the specified PDDL files for plan correctness. If you have developed your solution using a planner not mentioned in class, this should be clearly indicated in your report; however, the PDDL files will only be tested on editor.planning.domains, FF, or Fast Downward. Correctness will be assessed not only against the coursework requirements but also with respect to the specific implemented solution. (I.e., non-obvious or incorrect/missing action preconditions or effects may lead to strange plan output and mark deductions.) Up to 2 marks will be allocated for the correctness of the additional feature. The additional feature should be similar in terms of complexity to the requirements in the main specification (and may be more complex if you'd like), and you are encouraged to be creative in your solutions. Trivial additional features will receive very few marks.

Postgraduate students only: The scalability study demonstrated in the report will be assessed as part of the correctness mark, with 2 marks (of the total 15 marks allocated for correctness) reserved for the correctness of the scalability study.

0 **None**	**1-3** **Poor**	**4-6** **Fair**	**7-9** **Good**	**10-12** **Very good**	**13-15** **Excellent**
No source code submitted.	Weak solution. Many important requirements or test cases missing and/or not working perfectly.	Adequate solution. Some requirements implemented but important requirements missing. Test cases do not provide complete coverage. Some test cases may not work perfectly.	Thorough solution. Majority of requirements are met. Choice of test cases is convincing. Very few test cases do not work perfectly.	Very thorough solution. All requirements met and choice of test cases provides maximum coverage of requirements. Solution plans are quite convincing. Everything works perfectly.	Exceptional solution. All requirements are easily met and well demonstrated. Test cases are comprehensive and demonstrate robust behaviour. Everything works perfectly.

Additional notes

This is an **individual coursework** assignment. Both the reports and PDDL source code will be checked for plagiarism. You are responsible for ensuring that your submitted domain and problem files work correctly. The marker should not need to make any changes to the submitted files to get them to work. If the files do not run, the marker may test them on a second planner as a backup, but you should not rely on this.

Feedback

Individual written feedback will be provided to students approximately three working weeks after the submission of Coursework 1.

Learning Objectives

This coursework is meant to contribute to the following high-level aims for F29AI:

- To introduce the fundamental concepts and techniques of AI, including planning, search, and knowledge representation.
- To introduce the scope, subfields and applications of AI, including autonomous agents.
- To develop skills in AI programming in an appropriate language.

It is also meant to contribute to the following specific learning objectives for the course:

- Critical understanding of traditional AI problem solving and knowledge representation methods.
- Use of knowledge representation techniques (such as predicate logic).
- Critical understanding of different systematic and heuristic search techniques.
- Practice in expressing problems in terms of state-space search.
- Broad knowledge and understanding of the subfields and applications of AI.
- Detailed knowledge of one subfield of AI (e.g., planning) and ability to apply its formalisms and representations to small problems.
- Detailed understanding of different approaches to autonomous agent and robot architectures, and the ability to critically evaluate their advantages and disadvantages in different contexts.
- Practice in the implementation of simple AI systems using a suitable language.
- Identification, representation and solution of problems.
- Research skills and report writing.
- Practice in the use of information and communication technology (ICT), numeracy, and presentation skills.

Late submission of coursework

Coursework deadlines are fixed and individual coursework extensions will not be granted. Penalties for the late submission of coursework follow the university's policy on late submissions:

- The mark for coursework submitted late, but within 5 working days of the coursework deadline, will be reduced by 30%.
- Coursework submitted more than 5 working days after the deadline will not be marked.
- In a case where a student submits coursework up to 5 working days late, and the student has valid mitigating circumstances, the Mitigating Circumstances policy will apply. Students should submit a Mitigating Circumstances application for consideration by the Mitigating Circumstances Committee.

The MACS School policy on coursework submission is that the **deadline for coursework submissions**, whether hard-copy or online, is **3:30pm (Edinburgh local time)** for the Edinburgh Campus and **5:00pm (Dubai local time)** for the Dubai Campus. The University Policy on the Submission of Coursework can be found here: https://www.hw.ac.uk/services/docs/learning-teaching/policies/submissionofcoursework-policy.pdf

Mitigating Circumstances (MC)

There are circumstances which, through no fault of your own, may have affected your performance in an assessment (exams or other assessment), meaning that the assessment has not accurately measured your ability. These circumstances are described as **mitigating circumstances**. You can submit an application to have mitigating circumstances taken into account. Full details on the university's policies on mitigating circumstances and how to submit an application can be found here: https://www.hw.ac.uk/students/studies/examinations/mitigating-circumstances.htm

Plagiarism

"**Plagiarism** is the act of taking the ideas, writings or inventions of another person and using these as if they were your own, whether intentionally or not. Plagiarism occurs where there is no acknowledgement that the writings, or ideas, belong to or have come from another source." (Heriot-Watt University Plagiarism Policy). This coursework must be completed independently:

- Coursework reports must be written in a student's own words and any submitted code (e.g., PDDL) in the coursework must be your own code. Short sections of text or code taken from approved sources like the lecture examples may be included in the coursework provided these sources are **properly referenced**.
- Failure to reference work that has been obtained from other sources or to copy the words and/or code of another student is plagiarism and, if detected, this will be reported to the School's Discipline Committee. If a student is found guilty of plagiarism, the penalty could involve voiding the course.
- Students must **never** give hard or soft copies of their coursework reports or code to another student. Students must **always refuse** any request from another student for a copy of their report and/or code.
- Sharing a coursework report and/or code with another student is **collusion**, and if detected, this will be reported to the School's Discipline Committee. If found guilty of collusion, the penalty could involve voiding the course.

Plagiarism will be treated extremely seriously as an act of academic misconduct which will result in appropriate student discipline. All students should familiarise themselves with the university policies around plagiarism which can be found here: https://www.hw.ac.uk/students/studies/examinations/plagiarism.htm