F29AI – Artificial Intelligence and Intelligent Agents

Coursework – Search, Knowledge Representation, and Planning

You may work in groups of up to **three** people for this assignment. Your coursework will be worth 22% of your final grade. There are two main parts to the coursework with an additional part for Master's students.

Part I: Programming with A* Search

In this part, you will write a program that uses A* search to find a solution to the scenario described below. You may work in whatever programming language you are comfortable with and will be assessed on the quality and correctness of your program, and your understanding of the solution.

Problem description

A robot must load and unload packages into and out of a delivery truck. Packages unloaded from the delivery truck must be brought to the appropriate warehouse. Small packages must go to Warehouse A and large packages must go to Warehouse B. Medium packages, which are initially stored in either Warehouse A or Warehouse B, must be loaded onto the delivery truck. The truck initially contains S small packages and L large packages. Warehouse A initially contains M_a medium packages and Warehouse B initially contains M_b medium packages. Assume that both warehouses are adjacent to the truck and that the robot can freely move between the truck and the warehouses. The robot can only move one package at a time, regardless of size, from one location to another.

What to implement

Write a program that uses A* search to solve the above problem. You should design and implement an appropriate state space, transition function, heuristics, and goal encoding that models the problem description. The design of the state space is particularly important for this problem. As part of your program, you should implement two different heuristic functions to be used with A* search. You should also be prepared to explain the choice and operation of these heuristics. Ensure that your implementation will work with a number of different problem configurations of S, L, M_a, and M_b. You should test your implementation with small numbers of packages to ensure it is working correctly before testing it on larger numbers of packages.

What to hand in

- You should prepare a short video capture of your program running with captions or a voiceover describing its operation and output. Your video should be a maximum of 5 minutes long (and may be significantly shorter).

- You should submit your video along with the sourcecode of your program and a short report (maximum 2 pages) on Vision. Your report should briefly describe your solution, state space encoding, and your choice of heuristics.

Part II: Knowledge Representation and Automated Planning

In this part, you will model a planning domain in PDDL to satisfy the requirements in the problem description. You should use the planning tools available at http://planning.domains/, the distributed FF planner, or any other planner that supports PDDL (e.g., the Fast Downward planner is recommended). You will be assessed on the quality and correctness of your domain, and your understanding of the knowledge representation used to model the scenario.

Problem description

The Heriot-Watt SpacePort has decided to launch a new spaceship. Operations on board the spaceship will be controlled with plans generated by an AI planner that will direct the people, artificial agents, and the spaceship's controls. The ship itself is a large ship with multiple decks that are connected by lifts. Important locations on the ship include the bridge, engineering, sickbay, transporter room, shuttle bay, science lab, cargo bay, among others. The ship has different types of personnel on board: the captain, engineers, science officers, navigators, medical personnel, security staff, and the transporter chief. The ship has also been equipped with a group of robots that can move heavy equipment around the ship.

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

- The captain can order the ship to travel to a given destination, provided the captain is on the bridge.
- The ship can travel to another location provided it isn't damaged and there is a navigator on the bridge who has been given an appropriate order.
- Travelling to a planet that is in an asteroid belt damages the ship.
- Engineers can fix the ship from engineering.
- Personnel can move around a deck provided the rooms on the deck are connected by doors.
- Personnel can move between decks by using one of the lifts that are scattered around the ship.
- Personnel can transport to/from a planet from the transporter room.
- Small/light equipment can also be transported to/from a planet from the transporter room.
- After delivering heavy equipment the robots must recharge.
- The robots can only recharge from the science lab.
- Only the transporter chief can operate the transporter and only if it isn't damaged.
- Transporting plasma ore to the ship damages the transporter.
- Heavy equipment is stored in the cargo bay.
- A shuttlecraft can also be used to transport personnel and equipment to and from a planet.
- Medical supplies are kept in the sickbay.
- Injured crew members can be healed in the sickbay if medical personnel are present.

At launch, the ship is given a series of missions that it must complete. These missions might include relief missions to deliver medical supplies to certain planets, exploratory missions to study new planets, and first-contact missions to visit new worlds with intelligent life and establish diplomatic relations. Relief missions require the presence of medical personnel and medical supplies; exploratory missions require science officers and heavy equipment including a rover and communication station; and first-contact missions require the presence of the captain. Relief missions are successful if the appropriate personnel deliver the necessary supplies to the planet. Exploratory missions require a rock sample to be returned to the ship and delivered to the science lab. Some exploratory missions will require the collection of rock samples of a material called plasma. Due to the volatility of plasma ore, it can only be returned to the ship by transporter, rather than shuttlecraft. First-contact missions can be dangerous. If a planet is hostile and the ship's security personnel aren't present, the captain will be injured in the course of completing the mission. The ship initially starts at Earth and must return to Earth at the successful completion of its missions.

What to implement

For this question you must model the spaceship 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 design the knowledge representation necessary to encode this scenario as a planning problem. It is strongly recommended that you try to implement the domain incrementally, ensuring that some parts of the domain work correctly before moving on to other. You may also find that the planning time increases as you add more complexity to the domain. You may have to consider whether an alternative knowledge representation leads to a better solution to the problem. You may also find that the performance of the command line planners (e.g., FF and Fast Downward) outperforms that of the web-based planner. Make sure you test your encoding on a series of different missions. Some example missions will be distributed to the class closer to the deadline.

What to hand in

- You will demonstrate your solution in a live demonstration during the Week 8 lab. You will be assessed on the quality of your presentation, your ability to answer questions, as well as the correctness of your solution and your understanding of what you have done.

- You should submit your PDDL source, examples of successful plans, and a short report (maximum 2 pages) on Vision. Your report should outline your solution and highlight any interesting features of your domain encoding.

Master's Students Only

In addition to the above problems, Master's students should also answer the following questions.

- In Part II, design an additional feature of the domain (e.g., new personnel that can perform some task, a new ship's function, etc.) that isn't included in the above domain description. Add this feature to your domain and be prepared to demonstrate it during the live demonstration and discuss it in the report.

- How well does the spaceship domain scale? Choose a planning problem and increase the number of missions or personnel. 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 how robust your domain is and how you might improve it to scale to larger problem instances.

Deadlines

- **5 October (Week 4 Lab)**: Declare your project groups. Once declared, these groups are firm.
- **2 November (Week 8 Lab)**: Demonstrate your solution to Part II during the lab.
- **10 November**: Submit the files and documents from Part I and II, and your peer evaluation.

Assessment

This coursework will count towards 22% of your overall course mark. You will be assessed on the demonstration of your work, and the report detailing your solutions. A small component of your mark (2%) will also be based on peer evaluation. Details of how the peer evaluation process will work will be distributed closer to the deadline. The following mark distribution will be used:

Task	Undergraduates	Master's students
Part I	5	5
Part II Demonstration Report	 10 5	 8 7
Peer evaluation	2	2
TOTAL	**22**	**22**