AIND-Planning

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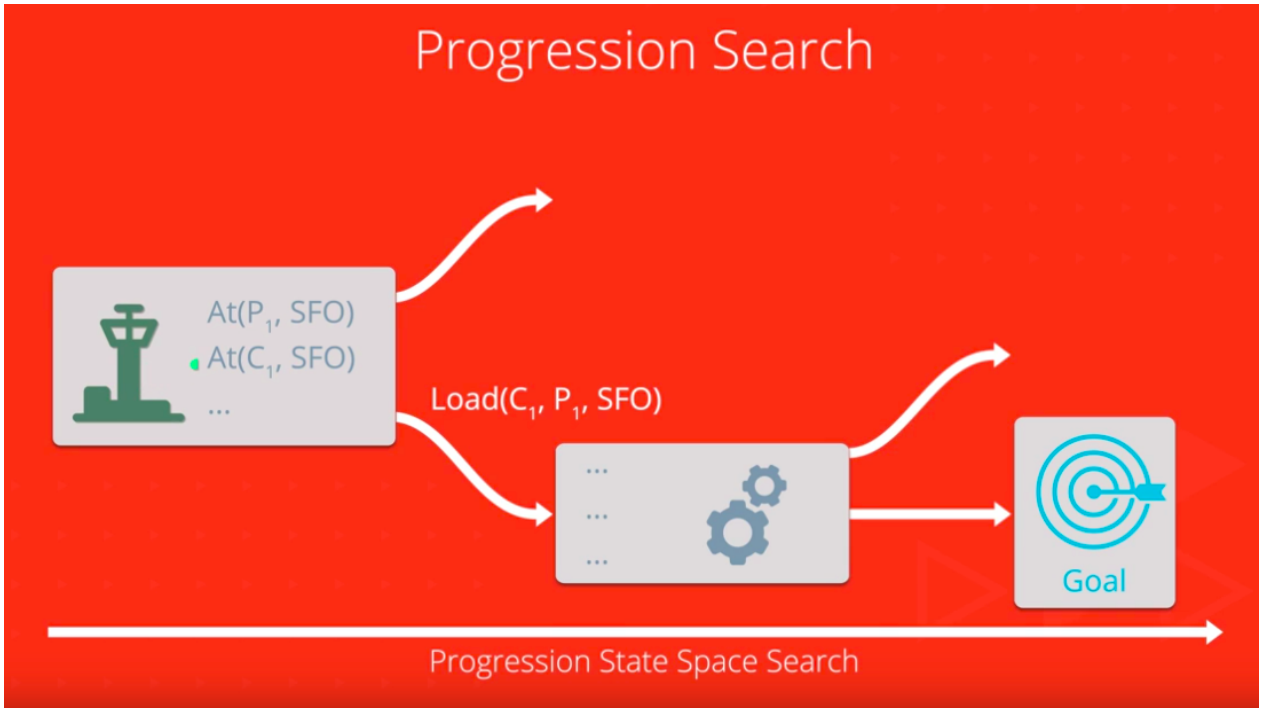
Implement a Planning Search

Synopsis

This project includes skeletons for the classes and functions needed to solve deterministic logistics planning problems for an Air Cargo transport system using a planning search agent. With progression search algorithms like those in the navigation problem from lecture, optimal plans for each problem will be computed. Unlike the navigation problem, there is no simple distance heuristic to aid the agent. Instead, you will implement domain-independent heuristics.



- Part 1 - Planning problems:
  - READ: applicable portions of the Russel/Norvig AIMA text
  - GIVEN: problems defined in classical PDDL (Planning Domain Definition Language)
  - TODO: Implement the Python methods and functions as marked in `my_air_cargo_problems.py`
  - TODO: Experiment and document metrics
- Part 2 - Domain-independent heuristics:
  - READ: applicable portions of the Russel/Norvig AIMA text

    - TODO: Implement relaxed problem heuristic in `my_air_cargo_problems.py`
    - TODO: Implement Planning Graph and automatic heuristic in `my_planning_graph.py`
    - TODO: Experiment and document metrics
- Part 3 - Written Analysis

Environment requirements

- Python 3.4 or higher
- Starter code includes a copy of companion code for the Stuart Russel/Norvig AIMA text.

Project Details

Part 1 - Planning problems

READ: Stuart Russel and Peter Norvig text:

"Artificial Intelligence: A Modern Approach" 3rd edition chapter 10 *or* 2nd edition Chapter 11 on Planning, available on the AIMA book site sections:

- *The Planning Problem*
- *Planning with State-space Search*

GIVEN: classical PDDL problems

All problems are in the Air Cargo domain. They have the same action schema defined, but different initial states and goals.

- Air Cargo Action Schema:

```
Action(Load(c, p, a),
        PRECOND: At(c, a) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)
        EFFECT: ¬ At(c, a) ∧ In(c, p))
Action(Unload(c, p, a),
        PRECOND: In(c, p) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)
        EFFECT: At(c, a) ∧ ¬ In(c, p))
Action(Fly(p, from, to),
        PRECOND: At(p, from) ∧ Plane(p) ∧ Airport(from) ∧ Airport(to)
        EFFECT: ¬ At(p, from) ∧ At(p, to))
```

- Problem 1 initial state and goal:

```
Init(At(C1, SFO) ∧ At(C2, JFK)
        ∧ At(P1, SFO) ∧ At(P2, JFK)
        ∧ Cargo(C1) ∧ Cargo(C2)
        ∧ Plane(P1) ∧ Plane(P2)
        ∧ Airport(JFK) ∧ Airport(SFO))
Goal(At(C1, JFK) ∧ At(C2, SFO))
```

- Problem 2 initial state and goal:

```
Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL)
        ∧ At(P1, SFO) ∧ At(P2, JFK) ∧ At(P3, ATL)
        ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3)
        ∧ Plane(P1) ∧ Plane(P2) ∧ Plane(P3)
        ∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL))
Goal(At(C1, JFK) ∧ At(C2, SFO) ∧ At(C3, SFO))
```

- Problem 3 initial state and goal:

```
Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL) ∧ At(C4, ORD)
        ∧ At(P1, SFO) ∧ At(P2, JFK)
        ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3) ∧ Cargo(C4)
        ∧ Plane(P1) ∧ Plane(P2)
        ∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL) ∧ Airport(ORD))
Goal(At(C1, JFK) ∧ At(C3, JFK) ∧ At(C2, SFO) ∧ At(C4, SFO))
```

TODO: Implement methods and functions in `my_air_cargo_problems.py`

- `AirCargoProblem.get_actions` method including `load_actions` and `unload_actions` sub-functions
- `AirCargoProblem.actions` method
- `AirCargoProblem.result` method
- `air_cargo_p2` function
- `air_cargo_p3` function

TODO: Experiment and document metrics for non-heuristic planning solution searches

- Run uninformed planning searches for `air_cargo_p1`, `air_cargo_p2`, and `air_cargo_p3`; provide metrics on number of node expansions required, number of goal tests, time elapsed, and optimality of solution for each search algorithm. Include the result of at least three of these searches, including breadth-first and depth-first, in your write-up (`breadth_first_search` and `depth_first_graph_search`).
- If depth-first takes longer than 10 minutes for Problem 3 on your system, stop the search and provide this information in your report.
- Use the `run_search` script for your data collection: from the command line type `python run_search -h` to learn more.

> **Why are we setting the problems up this way?**
>
> Progression planning problems can be solved with graph searches such as breadth-first, depth-first, and A*, where the nodes of the graph are "states" and edges are "actions". A "state" is the logical conjunction of all boolean ground "fluents", or state variables, that are possible for the problem using Propositional Logic. For example, we might have a problem to plan the transport of one cargo, C1, on a single available plane, P1, from one airport to another, SFO to JFK.
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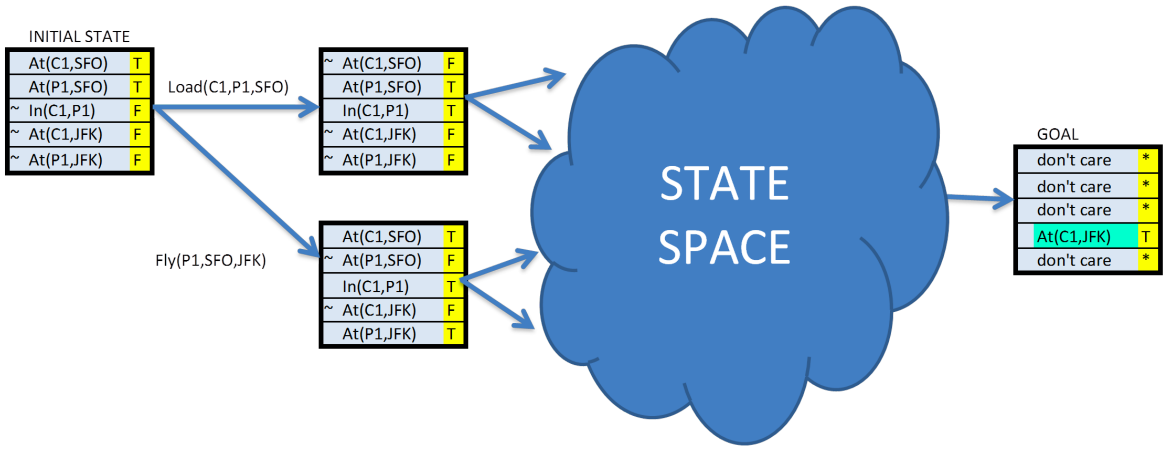
> 
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>
> In this simple example, there are five fluents, or state variables, which means our state space could be as large as $2^5 = 32$. Note the following:
>
> - While the initial state defines every fluent explicitly, in this case mapped to **TTFFF**, the goal may be a set of states. Any state that is `True` for the fluent `At(C1,JFK)` meets the goal.
> - Even though PDDL uses variable to describe actions as "action schema", these problems are not solved with First Order Logic. They are solved with Propositional logic and must therefore be defined with concrete (non-variable) actions and literal (non-variable) fluents in state descriptions.
> - The fluents here are mapped to a simple string representing the boolean value of each fluent in the system, e.g. **TTFFTT...TTF**. This will be the state representation in the `AirCargoProblem` class and is compatible with the `Node` and `Problem` classes, and the search methods in the AIMA library.

Part 2 - Domain-independent heuristics

READ: Stuart Russel and Peter Norvig text

"Artificial Intelligence: A Modern Approach" 3rd edition chapter 10 *or* 2nd edition Chapter 11 on Planning, available on the AIMA book site section:

- *Planning Graph*

TODO: Implement heuristic method in `my_air_cargo_problems.py`

- `AirCargoProblem.h_ignore_preconditions` method

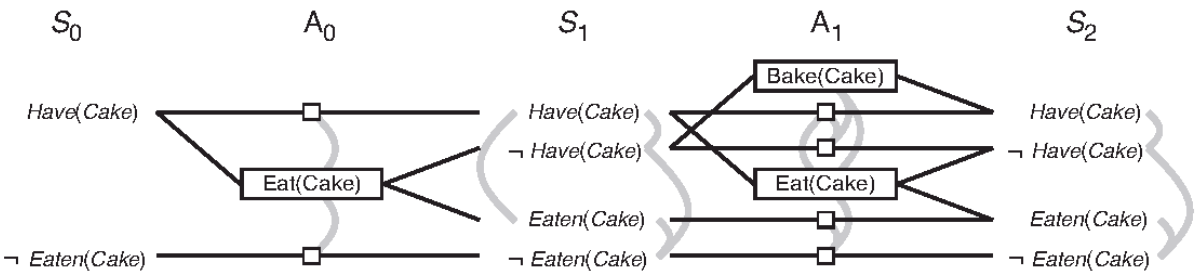
TODO: Implement a Planning Graph with automatic heuristics in `my_planning_graph.py`

- `PlanningGraph.add_action_level` method
- `PlanningGraph.add_literal_level` method
- `PlanningGraph.inconsistent_effects_mutex` method
- `PlanningGraph.interference_mutex` method
- `PlanningGraph.competing_needs_mutex` method
- `PlanningGraph.negation_mutex` method
- `PlanningGraph.inconsistent_support_mutex` method
- `PlanningGraph.h_levelsum` method

TODO: Experiment and document: metrics of A* searches with these heuristics

- Run A* planning searches using the heuristics you have implemented on `air_cargo_p1`, `air_cargo_p2` and `air_cargo_p3`. Provide metrics on number of node expansions required, number of goal tests, time elapsed, and optimality of solution for each search algorithm and include the results in your report.
- Use the `run_search` script for this purpose: from the command line type `python run_search -h` to learn more.

> **Why a Planning Graph?**
>
> The planning graph is somewhat complex, but is useful in planning because it is a polynomial-size approximation of the exponential tree that represents all possible paths. The planning graph can be used to provide automated admissible heuristics for any domain. It can also be used as the first step in implementing GRAPHPLAN, a direct planning algorithm that you may wish to learn more about on your own (but we will not address it here).

> *Planning Graph example from the AIMA book*
>
> 
>

Part 3: Written Analysis

TODO: Include the following in your written analysis.

- Provide an optimal plan for Problems 1, 2, and 3.
- Compare and contrast non-heuristic search result metrics (optimality, time elapsed, number of node expansions) for Problems 1,2, and 3. Include breadth-first, depth-first, and at least one other uninformed non-heuristic search in your comparison; Your third choice of non-heuristic search may be skipped for Problem 3 if it takes longer than 10 minutes to run, but a note in this case should be included.
- Compare and contrast heuristic search result metrics using A* with the "ignore preconditions" and "level-sum" heuristics for Problems 1, 2, and 3.
- What was the best heuristic used in these problems? Was it better than non-heuristic search planning methods for all problems? Why or why not?
- Provide tables or other visual aids as needed for clarity in your discussion.

Examples and Testing:

- The planning problem for the "Have Cake and Eat it Too" problem in the book has been implemented in the `example_have_cake` module as an example.
- The `tests` directory includes `unittest` test cases to evaluate your implementations. All tests should pass before you submit your project for review. From the AIND-Planning directory command line:
  - `python -m unittest tests.test_my_air_cargo_problems`

    - `python -m unittest tests.test_my_planning_graph`
- The `run_search` script is provided for gathering metrics for various search methods on any or all of the problems and should be used for this purpose.