Search in Python

Using AIMA Code

Today's topics

- AIMA Python code
- What it does
- How to use it
- Worked example: water jug program

Install AIMA Python ?

- Aimacode is a GitHub repo of python code linked to the AIMA book
- It's not available for pip installing ☹
  - Per Peter Norvig's recommendation
- Workarounds
  - Clone repo on computer & follow readme instructions
  - Add directory path to your PYTHONPATH env variable
  - Use it with Binder
- We'll put code we need in our 471 code-and-data repo

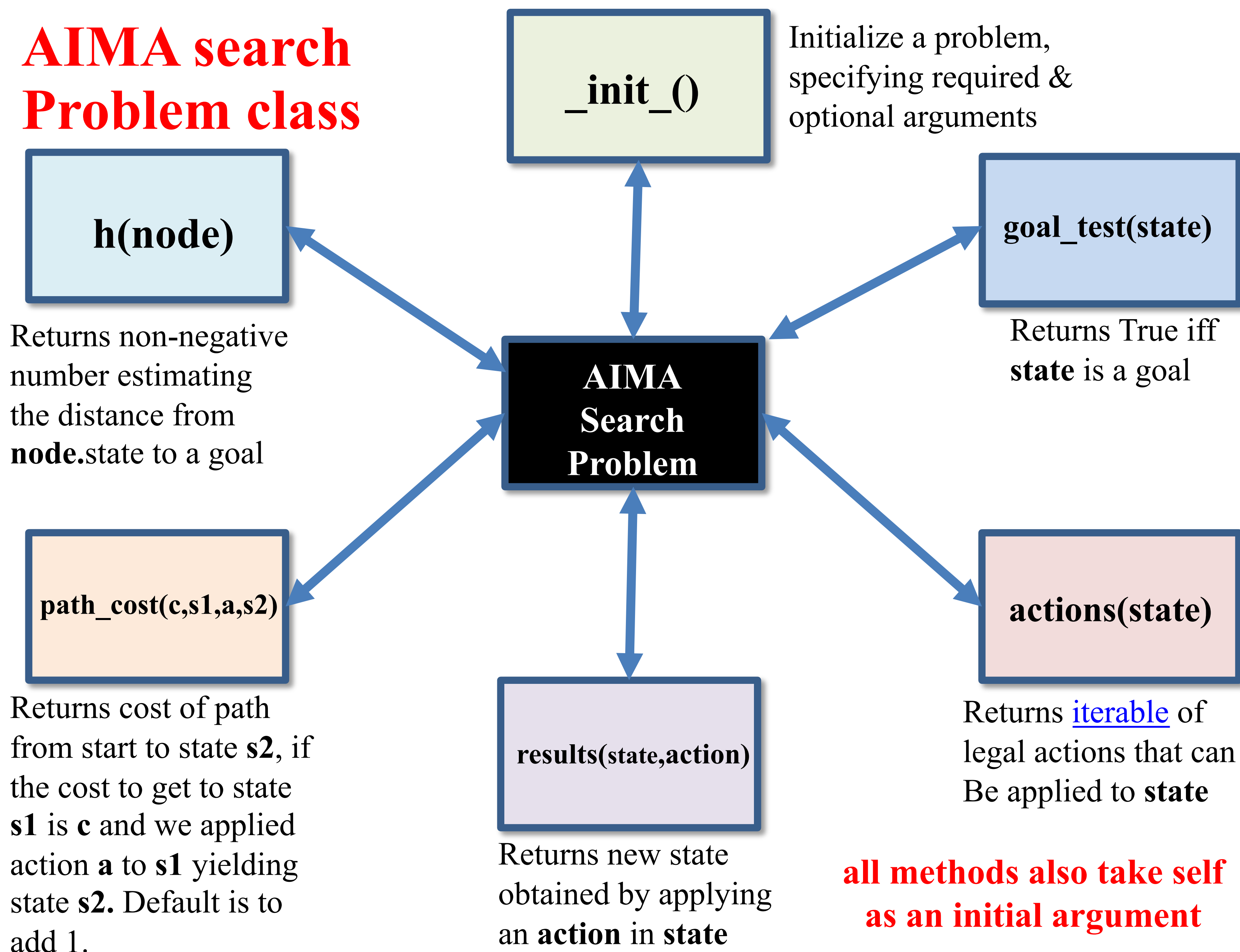
Two Water Jugs Problem

- Given two water jugs, J1 and J2, with capacities C1 and C2 and initial amounts W1 and W2, find actions to end up with amounts W1' and W2' in the jugs
- Example problem:
  - We have a 5-gallon and 2-gallon jug
  - Initially both are full
  - We want to end up with exactly one gallon in J2 and don't care how much is in J1

AIMA’s search.py

- Defines a *Problem* class for a search problem
- Has functions to do various kinds of search given an instance of a Problem, e.g., BFS, DFS, & more
- *InstrumentedProblem* subclasses *Problem* and is used with *compare_searchers* for evaluation
- To use for WJP:

1. Decide how to represent it (i.e., state, actions, goal);
2. Define *WJP* as a subclass of *Problem; and*
3. Provide methods to (a) create a WJP instance, (b) compute state successors, and (c) test for a goal


AIMA search Problem class
init()
Initialize a problem, specifying required & optional arguments
h(node)
Returns non-negative number estimating the distance from node.state to a goal
AIMA Search Problem
goal_test(state)
Returns True iff state is a goal
path_cost(c,s1,a,s2)
Returns cost of path from start to state s2, if the cost to get to state s1 is c and we applied action a to s1 yielding state s2. Default is to add 1.
results(state,action)
Returns new state obtained by applying an action in state
actions(state)
Returns iterable of legal actions that can Be applied to state
all methods also take self as an initial argument

Example: Water Jug Problem

Given full 5-gal. jug and empty 2-gal. jug, fill 2-gal jug with one gallon

- State = (x,y), where x is water in jug 1; y is water in jug 2
- Initial State = (5,0)
- Goal State = (-1,1), where -1 means any amount

Action table

Name	Cond.	Transition	Effect
dump1	$x>0$	$(x,y)\rightarrow(0,y)$	Empty Jug 1
dump2	$y>0$	$(x,y)\rightarrow(x,0)$	Empty Jug 2
pour_1_2	$x>0$ & $y<C2$	$(x,y)\rightarrow(x-D,y+D)$ $D = min(x,C2-y)$	Pour from Jug 1 to Jug 2
pour_2_1	$y>0$ & $X<C1$	$(x,y)\rightarrow(x+D,y-D)$ $D = min(y,C1-x)$	Pour from Jug 2 to Jug 1

Our WJ problem class

```
class WJ(Problem):
   def __init__(self, capacities=(5,2), initial=(5,0), goal=(0,1)):
      self.capacities = capacities
      self.initial = initial
      self.goal = goal
   def goal_test(self, state):  # returns True iff state is a goal state
      g = self.goal                # -1 is a don't care
      return (state[0] == g[0] or g[0] == -1 ) and
             (state[1] == g[1] or g[1] == -1)

  def __repr__(self):    # returns string representing the object
      return f"WJ({self.capacities},{self.initial},{self.goal}"
```

Note: f-string

Returns possible actions in state

```
def actions(self, state):
    (J1, J2) = state
    (C1, C2) = self.capacities
    if J1>0: yield(('dump’, 1, 0))
    if J2>0: yield(('dump’, 2, 0))
    if J2<C2 and J1>0: yield(('pour', 1, 2))
    if J1<C1 and J2>0: yield(('pour', 2, 1))
```

Note: we represent an action as a tuple of its name and arguments, e.g.

- *(dump, 1, 0)*
- *(pour 2, 1)*

yield? If you’re unfamiliar with yield and Python generators, see this.

Result returns successor state

```
def result(self, state, action):
    """ Given state and action, returns successor
        after doing action"""
    act, arg1, arg2 = action
    (J1, J2), (C1, C2) = state, self.capacities
    if act == 'dump':
        return (0, J2) if arg1 == 1 else (J1, 0)
    elif act == 'pour':
        if arg1 == 1:
            delta = min(J1, C2-J2)
            return (J1-delta, J2+delta)
        else:
            delta = min(J2, C1-J1)
            return (J1+delta, J2-delta)
     else:
            raise ValueError(f'Unknown action: {action}')
```

*Note: the AIMA code will call this for **each possible action** that can be done in a state*

So, we don't need to check if the action is possible in the state

Our WJ problem class

```
def h(self, node):
    # heuristic function that estimates distance
    # to a goal node
    return 0 if self.goal_test(node.state) else 1
```

Note: this is only useful for informed search algorithms

For uninformed algorithms, we don't worry about finding a least costly path

So, this heuristic just returns 0 got s goal node and 1 for anything else

Solving a WJP

```
code> python
>>> from wj import *                                  # Import wj.py and search.py
>>> from search import *
>>> p1 = WJ((5,2), (5,2), (-1, 1))                    # Create a problem instance
>>> p1
WJ((5, 2),(5, 2),(-1, 1))
>>> answer = breadth_first_graph_search(p1)           # Used the breadth 1st search function
>>> answer                                            # Will be None if the search failed or a
<Node (0, 1)>                                         #    a goal node in the search graph if successful
>>> answer.path_cost                                  # The cost to get to every node in the search graph
6                                                     #  is maintained by the search procedure
>>> path = answer.path()                              # A node's path is the best way to get to it from
>>> path                                              #   the start node, i.e., a solution
[<Node (5, 2)>, <Node (5, 0)>, <Node (3, 2)>, <Node (3, 0)>, <Node (1, 2)>, <Node (1, 0)>, <Node (0, 1)>]
```

Comparing Search Algorithms Results

Uninformed searches: breadth_first_tree_search, breadth_first_search, depth_first_graph_ search, iterative_deepening_search, depth_limited_ search

- All but depth_limited_search are **sound** (i.e., solutions found are correct)
- Not all are **complete** (i.e., can find all solutions)
- Not all are **optimal** (find best possible solution)
- Not all are **efficient**
- AIMA code has a comparison function

Comparing Search Algorithms Results

```
HW2> python
>>> from wj import *
>>> searchers=[breadth_first_graph_search, depth_first_graph_search,
iterative_deepening_search]
>>> compare_searchers([WJ((5,2), (5,0), (0,1))], ['SEARCH ALGORITHM',
'successors/goal tests/states generated/solution'], searchers)
SEARCH ALGORITHM            successors/goal tests/states generated/solution
breadth_first_graph_search     <   8 /   9 /  16 / (0, >
depth_first_graph_search       <   5 /   6 /  12 / (0, >
iterative_deepening_search     <  35 /  61 /  57 / (0, >
>>>
```

The Output

```
hhw2> python wjtest.py -s 5 0 -g 0 1
Solving WJ((5, 2),(5, 0),(0, 1)
   breadth_first_tree_search cost 5: (5, 0) (3, 2) (3, 0) (1, 2) (1, 0) (0, 1)
   breadth_first_search cost 5: (5, 0) (3, 2) (3, 0) (1, 2) (1, 0) (0, 1)
   depth_first_graph_search cost 5: (5, 0) (3, 2) (3, 0) (1, 2) (1, 0) (0, 1)
   iterative_deepening_search cost 5: (5, 0) (3, 2) (3, 0) (1, 2) (1, 0) (0, 1)
   astar_search cost 5: (5, 0) (3, 2) (3, 0) (1, 2) (1, 0) (0, 1)
SUMMARY: successors/goal tests/states generated/solution
breadth_first_tree_search    <  25/  26/  37/(0, >
breadth_first_graph_search   <   8/   9/  16/(0, >
depth_first_graph_search     <   5/   6/  12/(0, >
iterative_deepening_search   <  35/  61/  57/(0, >
astar_search                 <   8/  10/  16/(0, >
```

Water Jug Problem on Colab

- See our collection of AI notebooks on Colab and the code and data in our repo
- wj.ipynb which uses search.py