Search in Python

Chapter 3

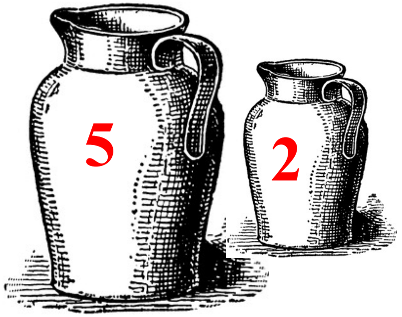
Today's topics

- 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
- One workaround is to:
  - Clone repo on your computer and follow instructions in its readme file
  - Add directory to your PYTHONPATH environment variable
  - Use it with Binder

Two Water Jugs Problem



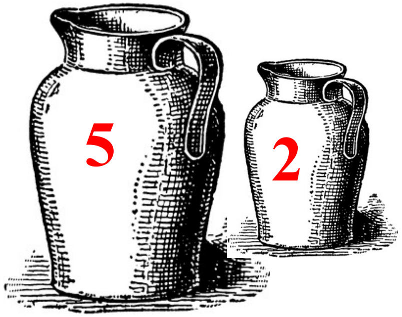
- Given two water jugs, J1 and J2, with capacities C1 and C2 and initial amounts W1 and W2, find actions to end up with amounts W1' and W2' in the jugs
- Example problem:
  - We have a 5 gallon and 2 gallon jug
  - Initially both are full
  - We want to end up with exactly one gallon in J2 and don't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

Example: Water Jug Problem



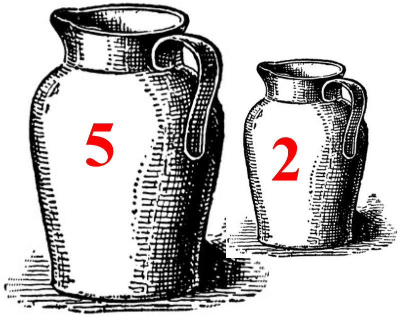
Given full 5-gal. jug and empty 2-gal. jug, fill 2-gal jug with one gallon

- 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)→(0,y)	Empty Jug 1
dump2	y>0	(x,y)→(x,0)	Empty Jug 2
pour_1_2	x>0 & y<C2	(x,y)→(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)→(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 list of possible actions in state

```
def actions(self, state):
    (J1, J2) = state
    (C1, C2) = self.capacities
    acts = []
    if J1>0: acts.append(('dump', 1))
    if J2>0: acts.append(('dump', 2))
    if J2<C2 and J1>0: acts.append(('pour', 1, 2))
    if J1<C1 and J2>0: acts.append(('pour', 2, 1))
    return acts   # returns empty list if none possible
```

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

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

Result returns successor state

```
def result(self, state, action):
   """ Given state and action, returns successor
      after doing action"""
   if len(action) == 2:     # eg (‘dump’, 1)
      act, arg1 = action
   else:                    # eg (‘pour’, 1, 2)
      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)
```

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

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_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
Python 2.7.6 |Anaconda 1.8.0 (x86_64)| ...
>>> from wj import *
>>> searchers=[breadth_first_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_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_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, >
```