Python Programming

```
from collections import OrderedDict

d = OrderedDict()
d['foo'] = 1
d['bar'] = 2
d['spam'] = 3
d['grok'] = 4

# Outputs "foo 1", "bar 2", "spam 3", "grok 4"
for key in d:
    print(key, d[key])
```

```
>>> import json
>>> json.dumps(d)
'{"foo": 1, "bar": 2, "spam": 3, "grok": 4}'
>>>
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```
prices = {
    'ACME': 45.23,
    'AAPL': 612.78,
    'IBM': 205.55,
    'HPQ': 37.20,
    'FB': 10.75
}
```

```
min_price = min(zip(prices.values(), prices.keys()))
# min_price is (10.75, 'FB')

max_price = max(zip(prices.values(), prices.keys()))
# max_price is (612.78, 'AAPL')

prices_sorted = sorted(zip(prices.values(), prices.keys()))
# prices_sorted is [(10.75, 'FB'), (37.2, 'HPQ'),
#                   (45.23, 'ACME'), (205.55, 'IBM'),
#                   (612.78, 'AAPL')]

prices_and_names = zip(prices.values(), prices.keys())
print(min(prices_and_names))   # OK
print(max(prices_and_names))   # ValueError: max() arg is an empty sequence
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```
prices = {
   'ACME': 45.23,
   'AAPL': 612.78,
   'IBM': 205.55,
   'HPQ': 37.20,
   'FB': 10.75
}
```

```
min(prices)   # Returns 'AAPL'
max(prices)   # Returns 'IBM'

min(prices.values())  # Returns 10.75
max(prices.values())  # Returns 612.78

min(prices, key=lambda k: prices[k])  # Returns 'FB'
max(prices, key=lambda k: prices[k])  # Returns 'AAPL'

min_value = prices[min(prices, key=lambda k: prices[k])]

>>> prices = { 'AAA' : 45.23, 'ZZZ': 45.23 }
>>> min(zip(prices.values(), prices.keys()))
(45.23, 'AAA')
>>> max(zip(prices.values(), prices.keys()))
(45.23, 'ZZZ')
>>>
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```
a = {
    'x' : 1,
    'y' : 2,
    'z' : 3
}

b = {
    'w' : 10,
    'x' : 11,
    'y' : 2
}
```

```
# Find keys in common
a.keys() & b.keys()   # { 'x', 'y' }

# Find keys in a that are not in b
a.keys() - b.keys()   # { 'z' }

# Find (key,value) pairs in common
a.items() & b.items() # { ('y', 2) }

# Make a new dictionary with certain keys removed
c = {key:a[key] for key in a.keys() - {'z', 'w'}}
# c is {'x': 1, 'y': 2}
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```python
def dedupe(items):
    seen = set()
    for item in items:
        if item not in seen:
            yield item
            seen.add(item)
```

```python
def dedupe(items, key=None):
    seen = set()
    for item in items:
        val = item if key is None else key(item)
        if val not in seen:
            yield item
            seen.add(val)
```

```
>>> a = [1, 5, 2, 1, 9, 1, 5, 10]
>>> list(dedupe(a))
[1, 5, 2, 9, 10]
>>>
```

```
>>> a = [ {'x':1, 'y':2}, {'x':1, 'y':3}, {'x':1, 'y':2}, {'x':2, 'y':4}]
>>> list(dedupe(a, key=lambda d: (d['x'],d['y'])))
[{'x': 1, 'y': 2}, {'x': 1, 'y': 3}, {'x': 2, 'y': 4}]
>>> list(dedupe(a, key=lambda d: d['x']))
[{'x': 1, 'y': 2}, {'x': 2, 'y': 4}]
>>>
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```
######    0123456789012345678901234567890123456789012345678901234567890'
record = '.....................100          .......513.25     ..........'
cost = int(record[20:32]) * float(record[40:48])
```

```
SHARES = slice(20,32)
PRICE  = slice(40,48)

cost = int(record[SHARES]) * float(record[PRICE])
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```
>>> items = [0, 1, 2, 3, 4, 5, 6]
>>> a = slice(2, 4)
>>> items[2:4]
[2, 3]
>>> items[a]
[2, 3]
>>> items[a] = [10,11]
>>> items
[0, 1, 10, 11, 4, 5, 6]
>>> del items[a]
>>> items
[0, 1, 4, 5, 6]
```

```
>>> a = slice(10, 50, 2)
>>> a.start
10
>>> a.stop
50
>>> a.step
2

>>> s = 'HelloWorld'
>>> a.indices(len(s))
(5, 10, 2)
>>> for i in range(*a.indices(len(s))):
...     print(s[i])
...
W
r
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```
words = [
    'look', 'into', 'my', 'eyes', 'look', 'into', 'my', 'eyes',
    'the', 'eyes', 'the', 'eyes', 'the', 'eyes', 'not', 'around', 'the',
    'eyes', "don't", 'look', 'around', 'the', 'eyes', 'look', 'into',
    'my', 'eyes', "you're", 'under'
]

from collections import Counter
word_counts = Counter(words)
top_three = word_counts.most_common(3)
print(top_three)
# Outputs [('eyes', 8), ('the', 5), ('look', 4)]
```

```
>>> word_counts['not']
1
>>> word_counts['eyes']
8
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

```
>>> morewords = ['why','are','you','not','looking','in','my','eyes']
>>> for word in morewords:
...     word_counts[word] += 1


>>> word_counts['eyes']
9


>>> word_counts.update(morewords)
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

Python Programming

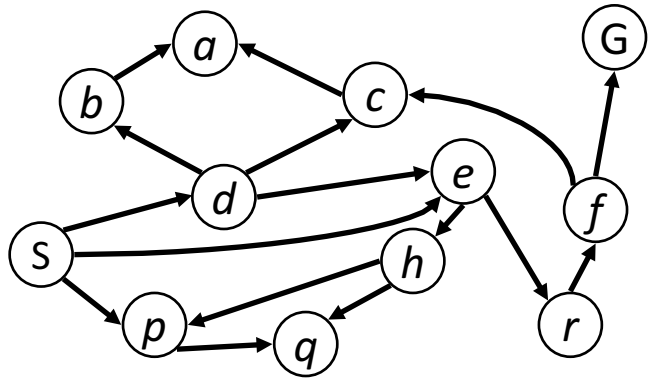
```
>>> a = Counter(words)
>>> b = Counter(morewords)
>>> a
Counter({'eyes': 8, 'the': 5, 'look': 4, 'into': 3, 'my': 3, 'around': 2,
         "you're": 1, "don't": 1, 'under': 1, 'not': 1})
>>> b
Counter({'eyes': 1, 'looking': 1, 'are': 1, 'in': 1, 'not': 1, 'you': 1,
         'my': 1, 'why': 1})

>>> # Combine counts
>>> c = a + b
>>> c
Counter({'eyes': 9, 'the': 5, 'look': 4, 'my': 4, 'into': 3, 'not': 2,
         'around': 2, "you're": 1, "don't": 1, 'in': 1, 'why': 1,
         'looking': 1, 'are': 1, 'under': 1, 'you': 1})

>>> # Subtract counts
>>> d = a - b
>>> d
Counter({'eyes': 7, 'the': 5, 'look': 4, 'into': 3, 'my': 2, 'around': 2,
         "you're": 1, "don't": 1, 'under': 1})
```

Source: Beazley, David; Jones, Brian K. (2013). *Python Cookbook* (3rd ed.).

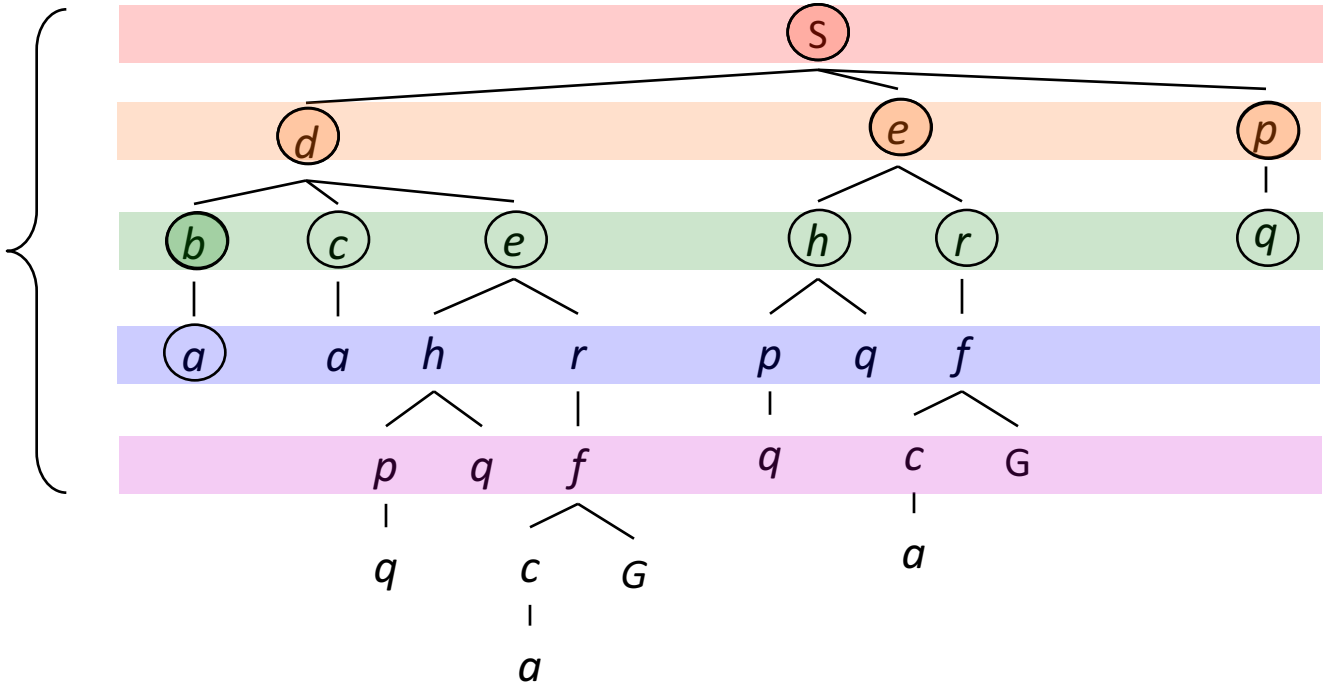
Breadth-First Search

Strategy: expand a shallowest node first

Implementation: Fringe is a FIFO queue



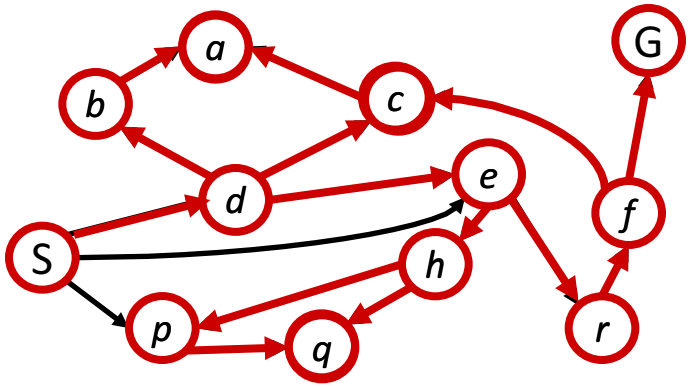
Search Tiers

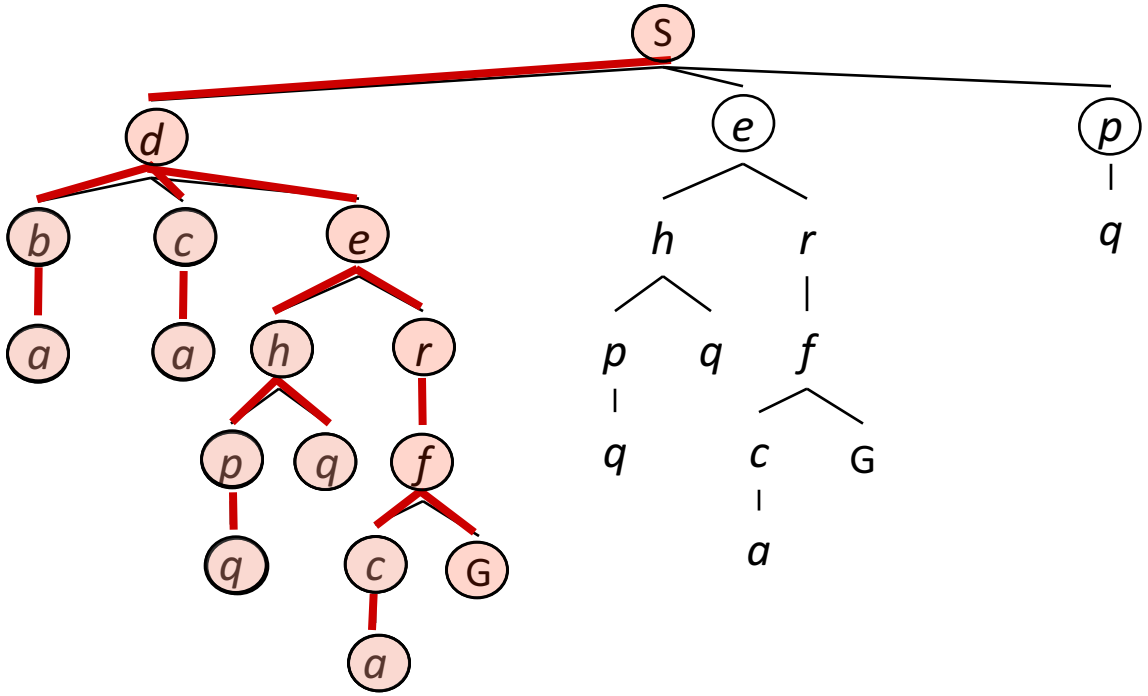


Depth-First Search

Strategy: expand a deepest node first

Implementation: Fringe is a LIFO stack



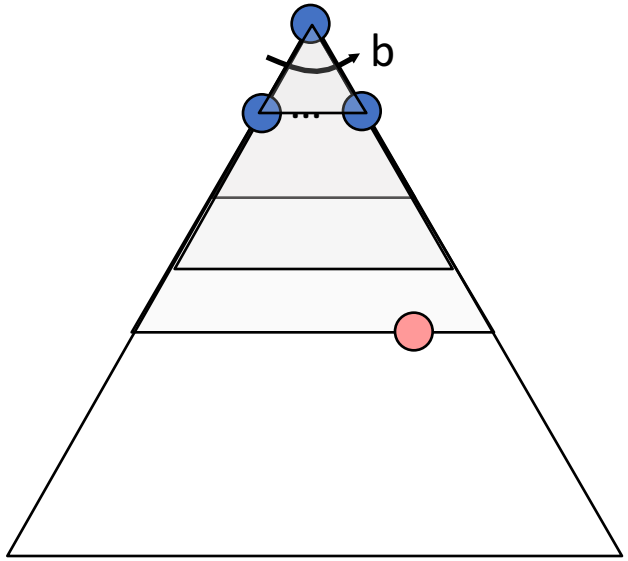


DFS vs BFS

- If you know a solution is not far from the root of the tree, a breadth first search (BFS) might be better.
- If the tree is very deep and solutions are rare, depth first search (DFS) might take an extremely long time, but BFS could be faster.
- If the tree is very wide, a BFS might need too much memory, so it might be completely impractical.
- If solutions are frequent but located deep in the tree, BFS could be impractical.
- If the search tree is very deep you will need to restrict the search depth for depth first search (DFS), anyway (for example with iterative deepening).

Iterative Deepening

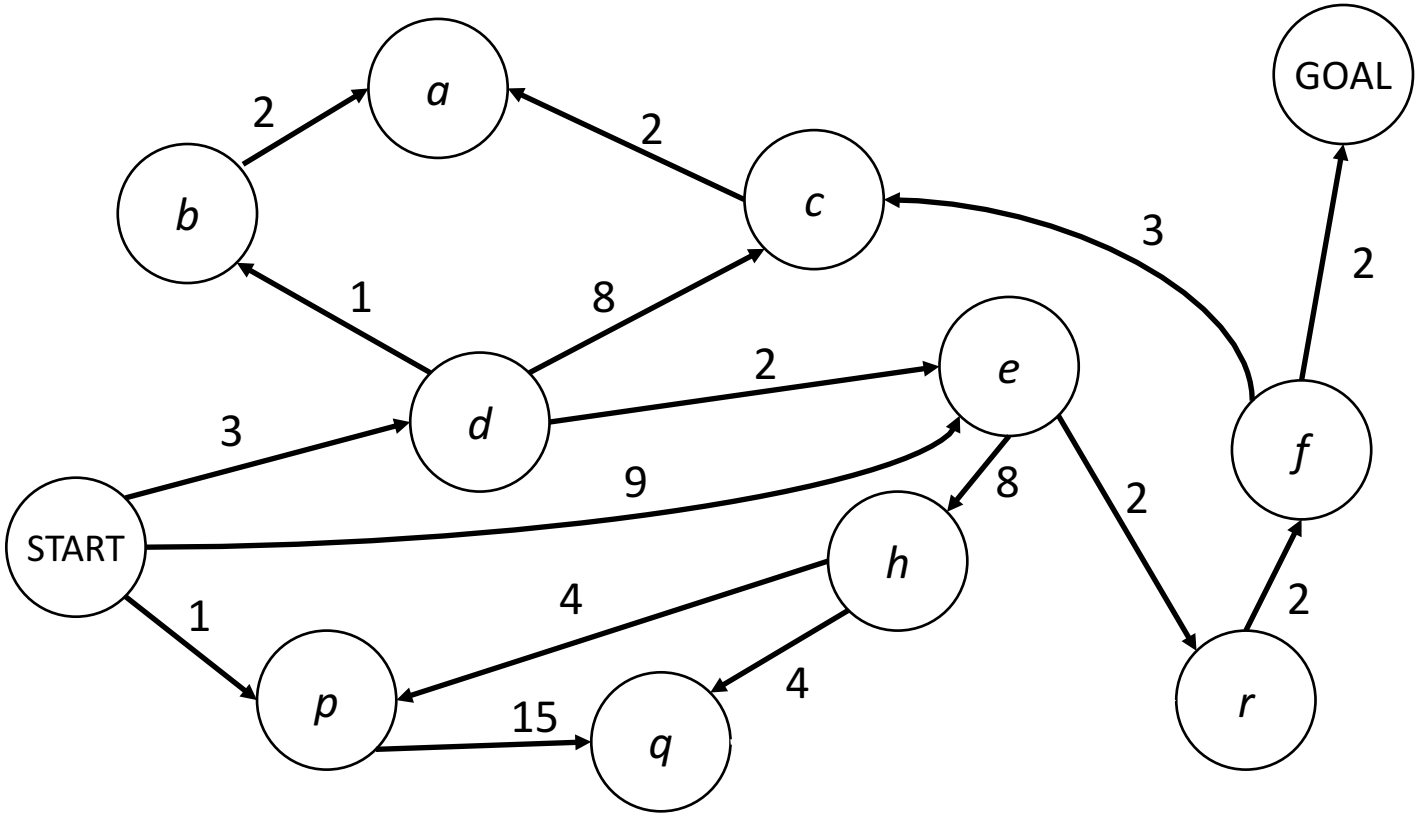
- Idea: get DFS's space advantage with BFS's time / shallow-solution advantages
  - Run a DFS with depth limit 1. If no solution…
  - Run a DFS with depth limit 2. If no solution…
  - Run a DFS with depth limit 3. …..
- Isn't that wastefully redundant?
  - Generally most work happens in the lowest level searched, so not so bad!



Python Code for Iterative Deepening

```
# A function to perform a Depth-Limited search
# from given source 'src'
def DLS(src,target,maxDepth):

    if src == target : return True

    # If reached the maximum depth, stop recursing.
    if maxDepth <= 0 : return False

    # Recur for all the vertices adjacent to this vertex
    for i in graph[src]:
            if(DLS(i,target,maxDepth-1)):
                return True
    return False

# IDDFS to search if target is reachable from v.
# It uses recursive DLS()
def IDDFS(src,target, maxDepth):

    # Repeatedly depth-limit search till the
    # maximum depth
    for i in range(maxDepth):
        if (DLS(src, target, i)):
            return True
    return False
```

Cost-Sensitive Search

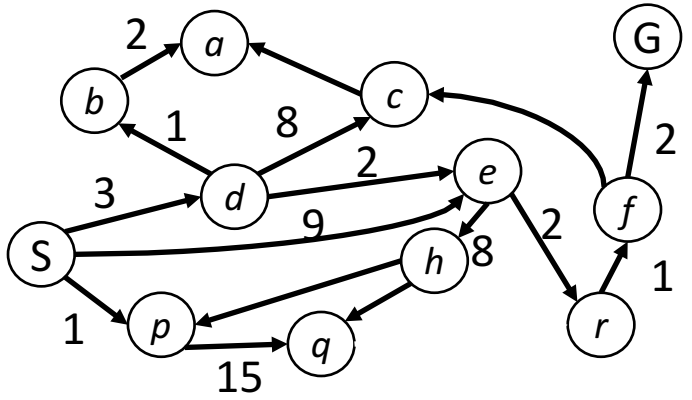


BFS finds the shortest path in terms of number of actions.
It does not find the least-cost path. We will now cover
a similar algorithm which does find the least-cost path.

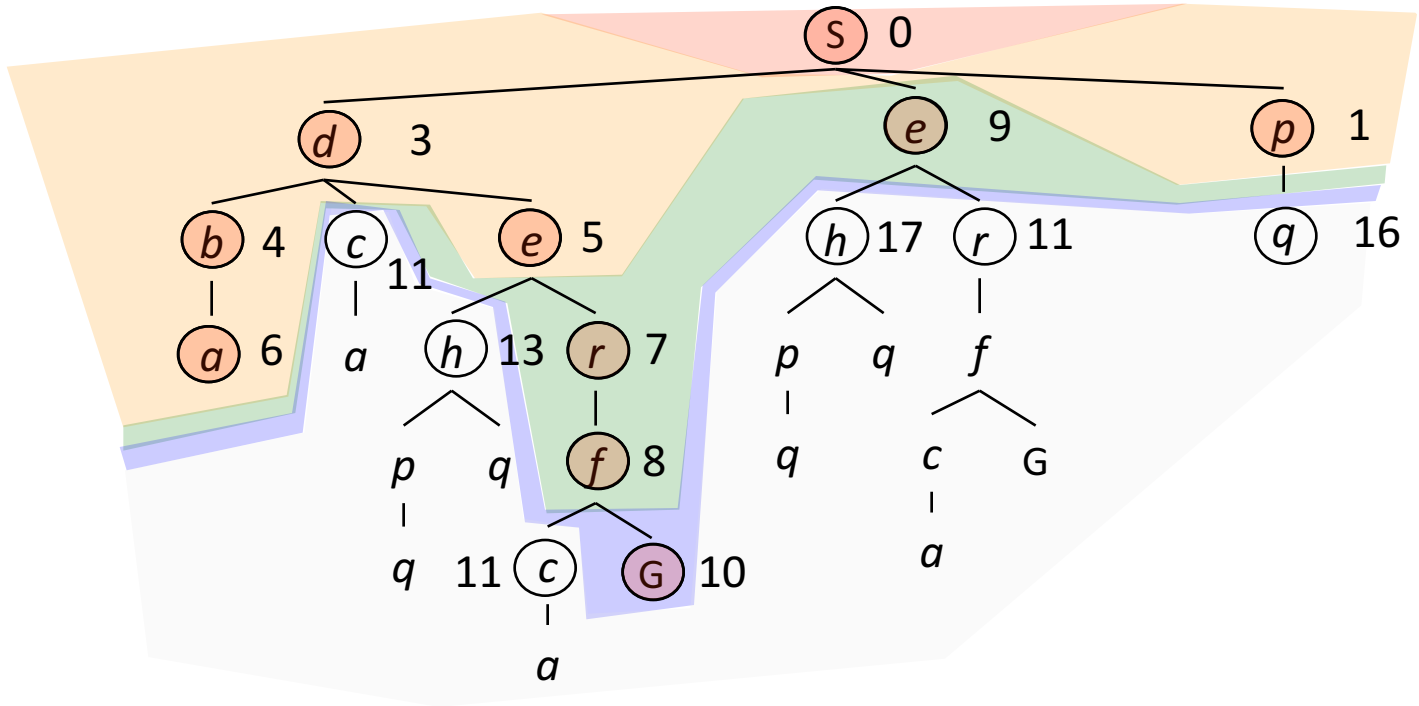
Uniform Cost Search

Strategy: expand a cheapest node first:

Fringe is a priority queue (priority: cumulative cost)

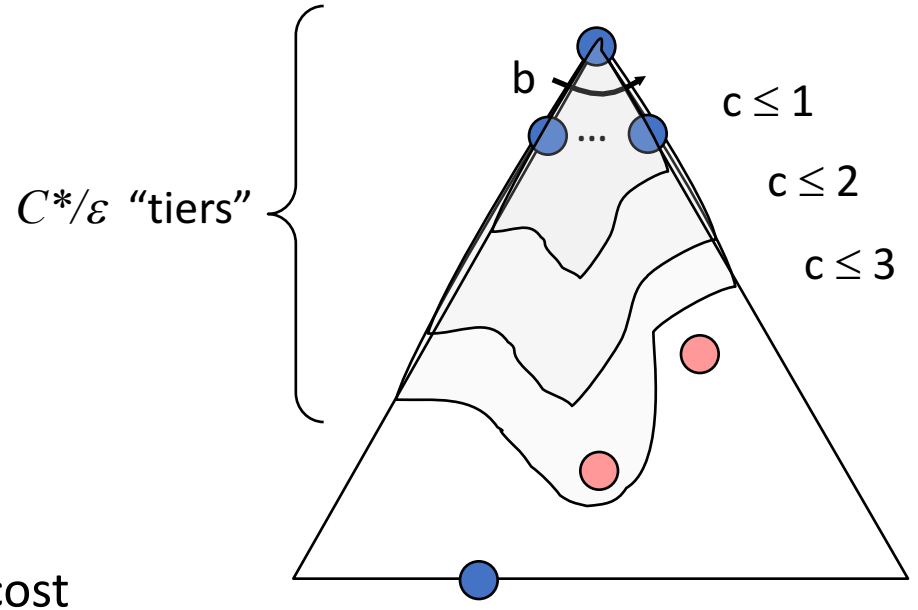


Cost contours



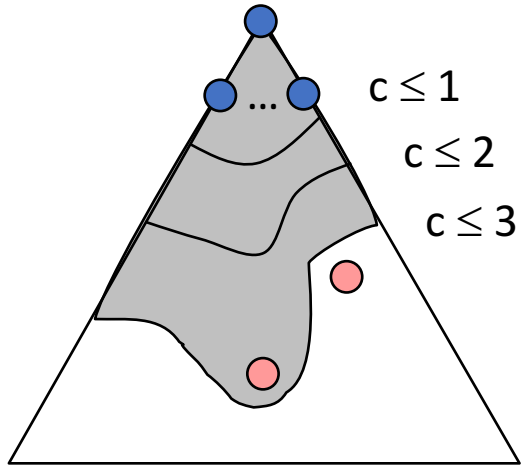
Uniform Cost Search (UCS) Properties

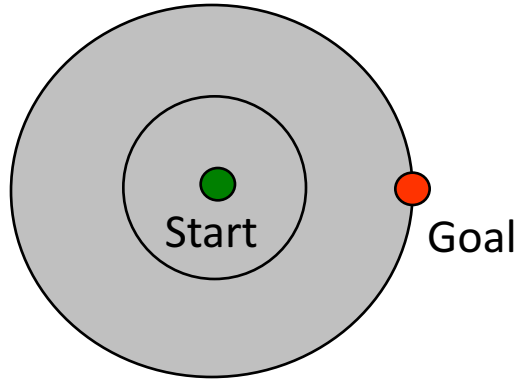
- What nodes does UCS expand?
  - Processes all nodes with cost less than cheapest solution!
  - If that solution costs C^* and arcs cost at least ε, then the "effective depth" is roughly C^*/ε
  - Takes time $O(b^{C^*/\varepsilon})$ (exponential in effective depth)
- How much space does the fringe take?
  - Has roughly the last tier, so $O(b^{C^*/\varepsilon})$
- Is it complete?
  - Assuming best solution has a finite cost and minimum arc cost is positive, yes!
- Is it optimal?
  - Yes! (skipping the proof for now)



Uniform Cost Issues

- Remember: UCS explores increasing cost contours
- The good: UCS is complete and optimal!
- The bad:
  - Explores options in every “direction”
  - No information about goal location
- We’ll fix that soon!





BFS/DFS/UCS

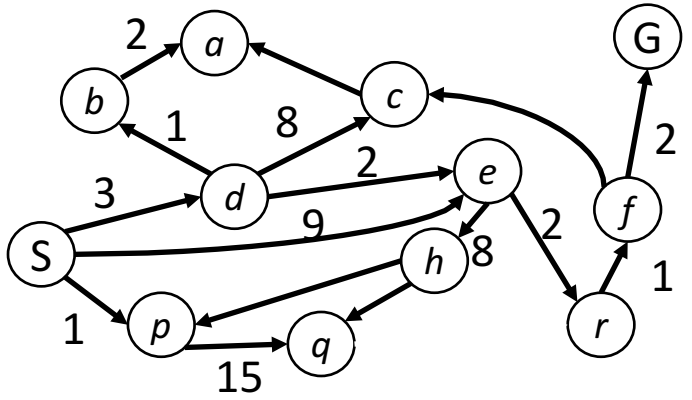
- **Breadth-first search**
  - Good: optimal, works well when many options, but not many actions required
  - Bad: assumes all actions have equal cost
- **Depth-first search**
  - Good: memory-efficient, works well when few options, but lots of actions required
  - Bad: not optimal, can run infinitely, assumes all actions have equal cost
- **Uniform-cost search**
  - Good: optimal, handles variable-cost actions
  - Bad: explores all options, no information about goal location

Basically Dijkstra's Algorithm!

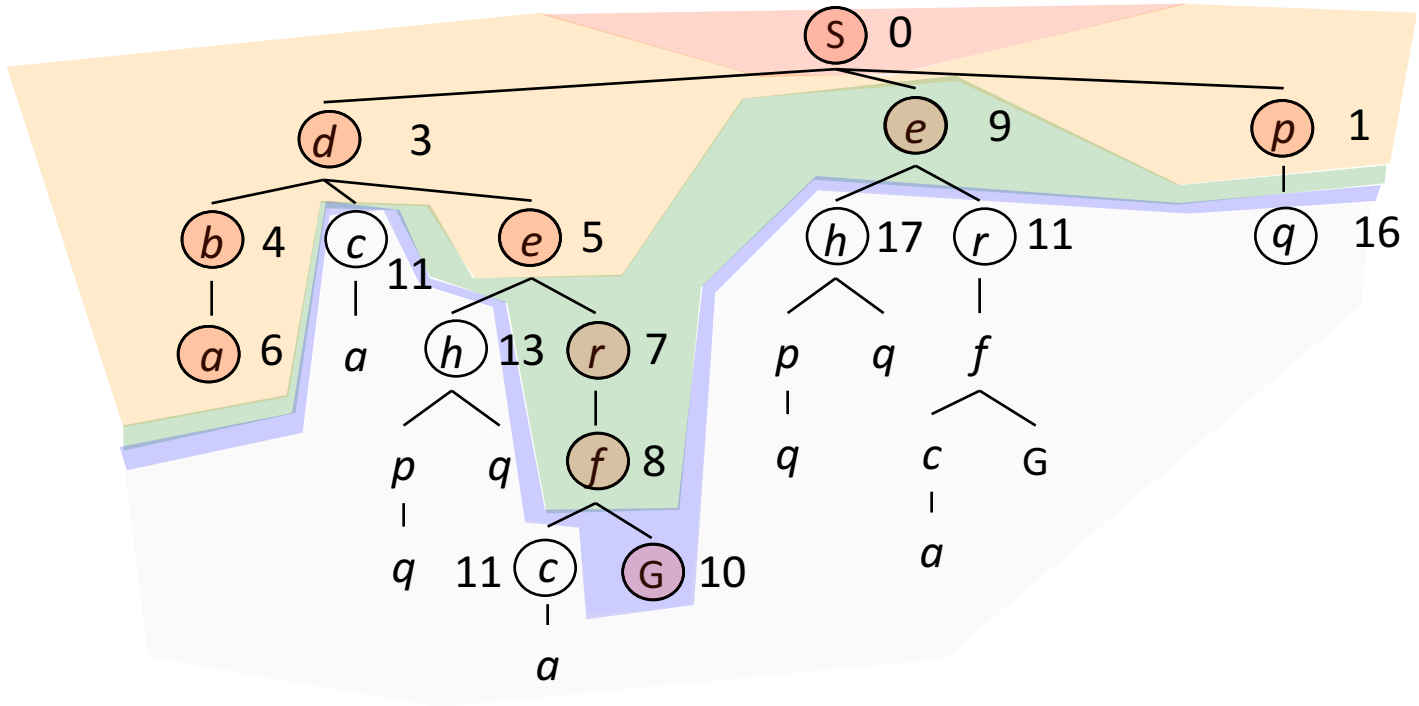
Dijkstra‘s algorithm (Uniform-cost search)

Strategy: expand a cheapest node first:

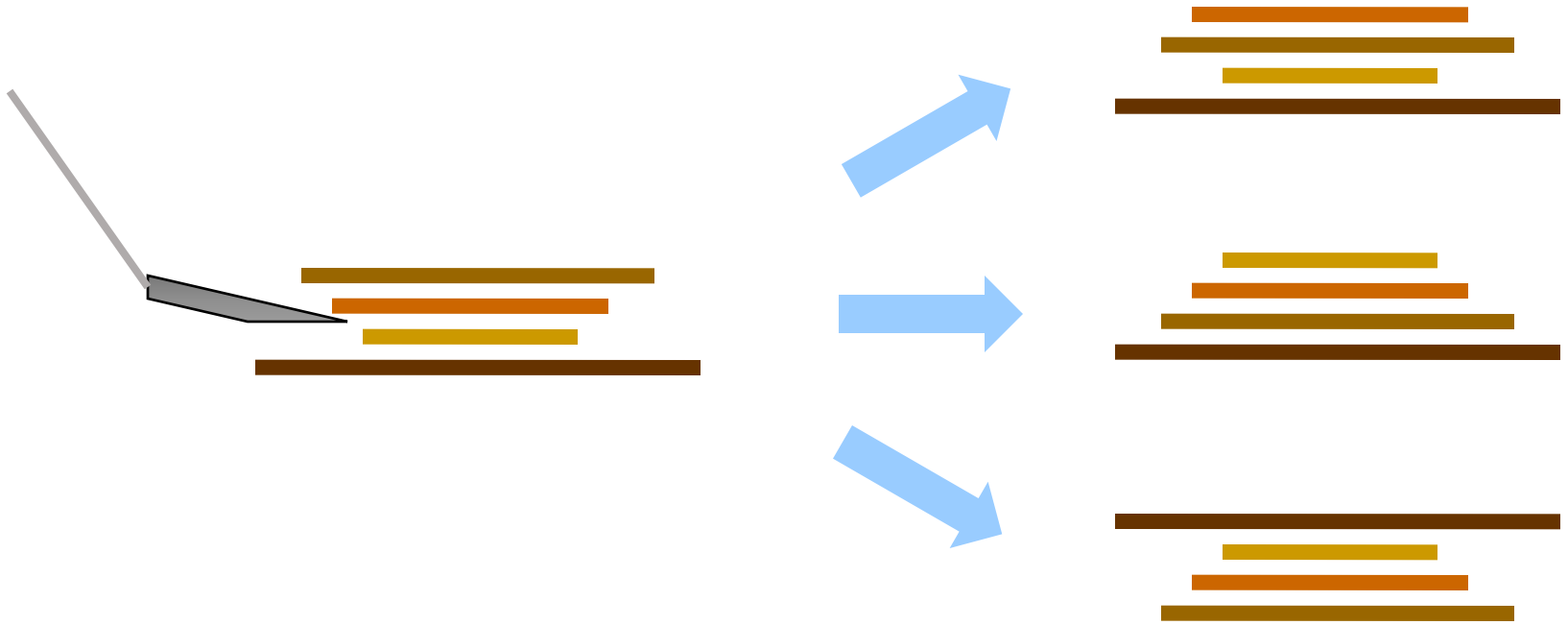
Fringe is a priority queue (priority: cumulative cost)



Cost contours



Search example: Pancake Problem



Rule: a spatula can be inserted at any interval and flip all pancakes above it.

Cost: Number of pancakes flipped.

Pancake BFS

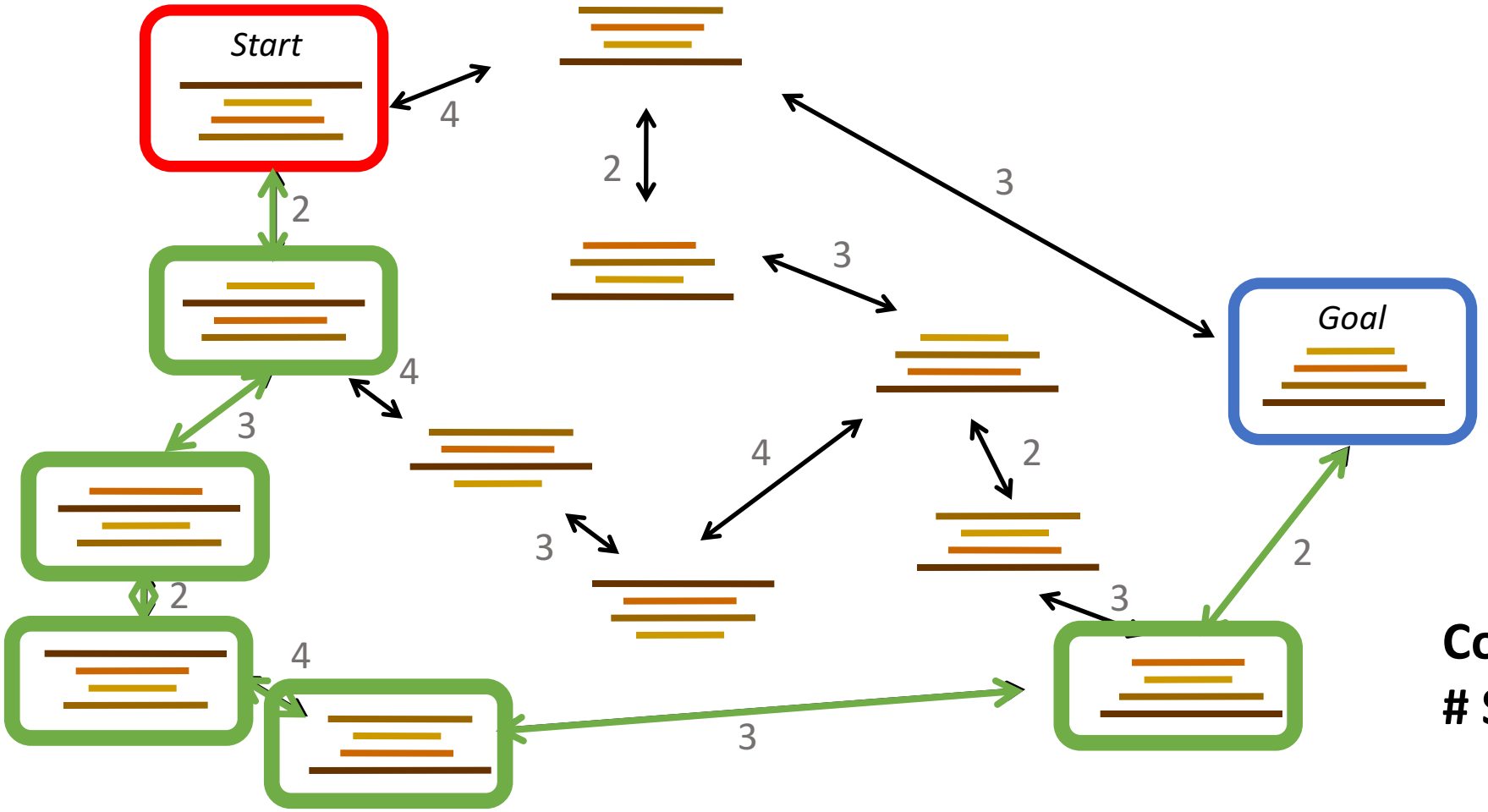
Draw it by yourself!

Pancake UCS

Draw it by yourself!

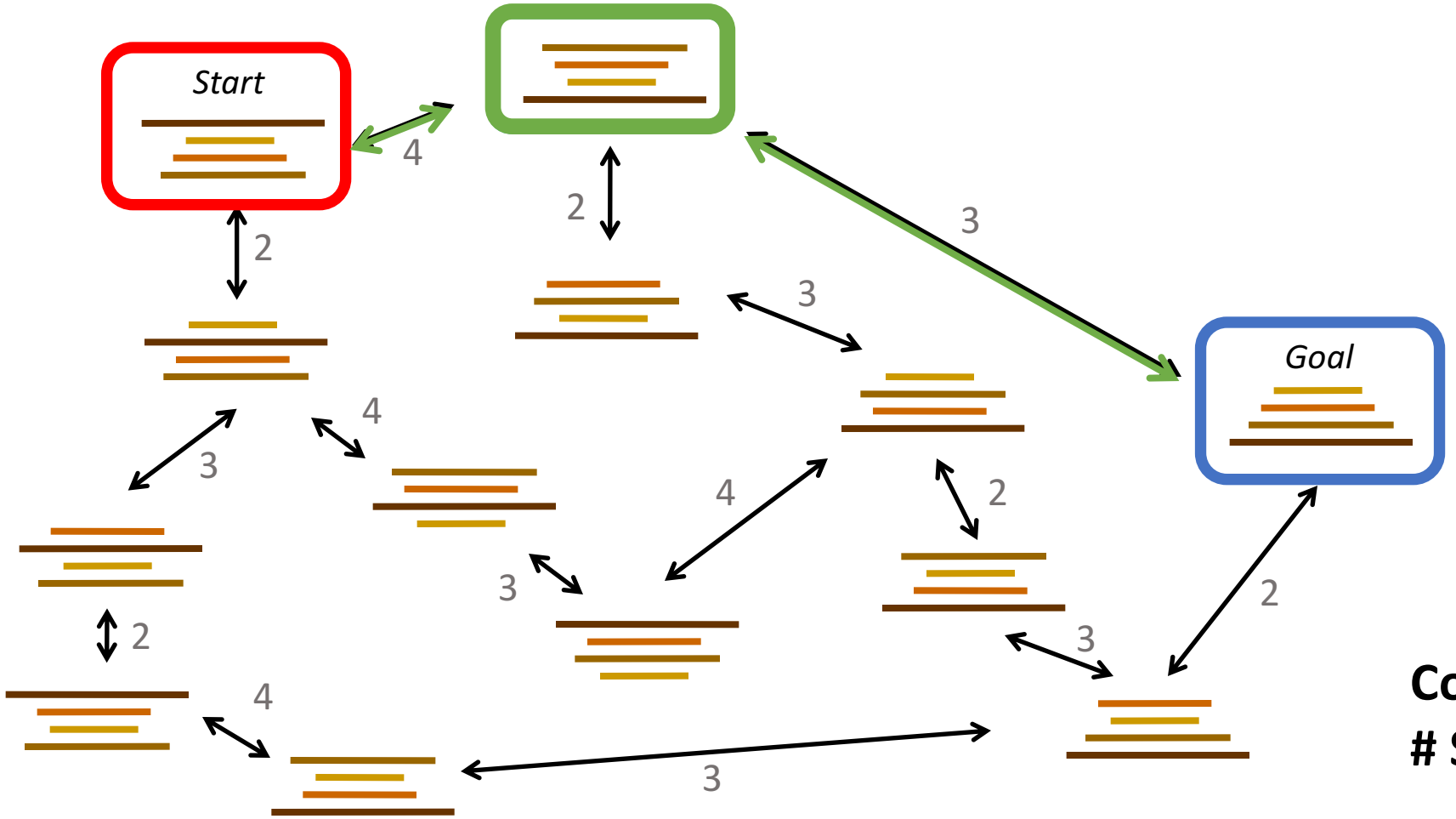
Pancake DFS

State space graph with costs as weights



Pancake Optimal

State space graph with costs as weights



Cost: 7

 # Steps: 2

Project 1: Search (due 09/13)

Question 1 (3 points): Finding a Fixed Food Dot using Depth First Search

In `searchAgents.py`, you'll find a fully implemented `SearchAgent`, which plans out a path through Pacman's world and then executes that path step-by-step. The search algorithms for formulating a plan are not implemented -- that's your job.

First, test that the `SearchAgent` is working correctly by running:

```
python pacman.py -l tinyMaze -p SearchAgent -a fn=tinyMazeSearch
```

Question 2 (3 points): Breadth First Search

Implement the breadth-first search (BFS) algorithm in the `breadthFirstSearch` function in `uninformed_search.py`. Again, write a graph search algorithm that avoids expanding any already visited states. Test your code the same way you did for depth-first search.

```
python pacman.py -l mediumMaze -p SearchAgent -a fn=bfs
```

Question 3 (4 points): Uniform Cost Search

While BFS will find a fewest-actions path to the goal, we might want to find paths that are "best" in other senses. Consider `mediumDottedMaze`, where food is concentrated in the eastern half of the map, and `mediumScaryMaze`, where that side of the map is full of ghosts.

By changing the cost function, we can encourage Pacman to find different paths through the maze. For example, we can charge more for steps in the eastern half of the map when it's full of dangerous ghosts, and less when it's full of tasty pellets, and a rational Pacman agent should adjust its behavior in response.

Implement the uniform-cost graph search algorithm in the `uniformCostSearch` function in `uninformed_search.py`.

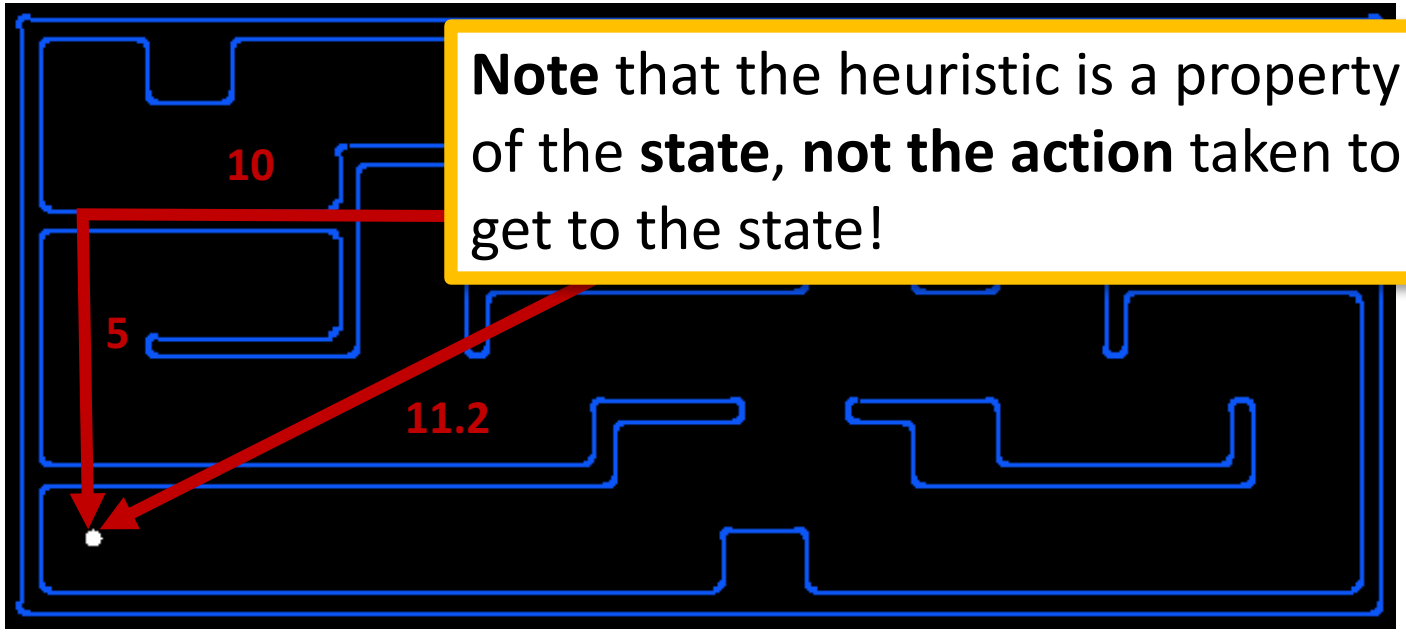
Incorporating goal information

How to efficiently solve search problems with variable-cost actions, using information about the goal state?

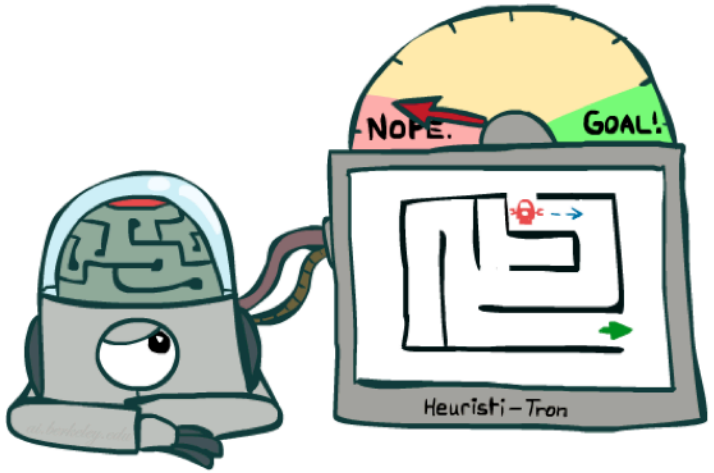
- Heuristics
- Greedy approach
- A* search

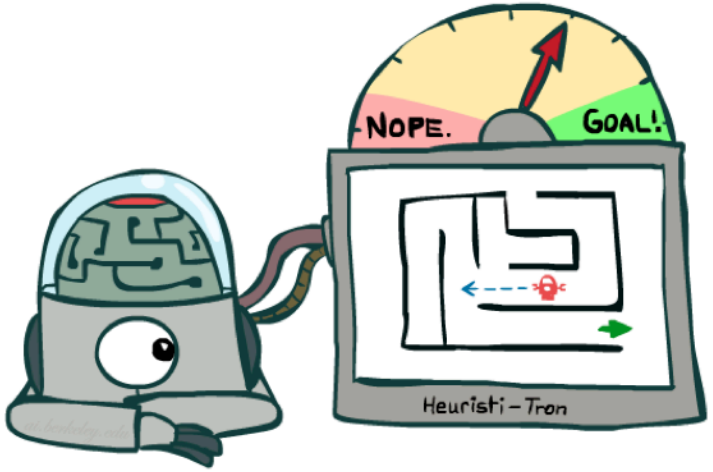
Search Heuristics

- A heuristic is:
  - A function that *estimates* how close a state is to a goal
  - Designed for a particular search problem
  - Examples: Manhattan distance, Euclidean distance for pathing



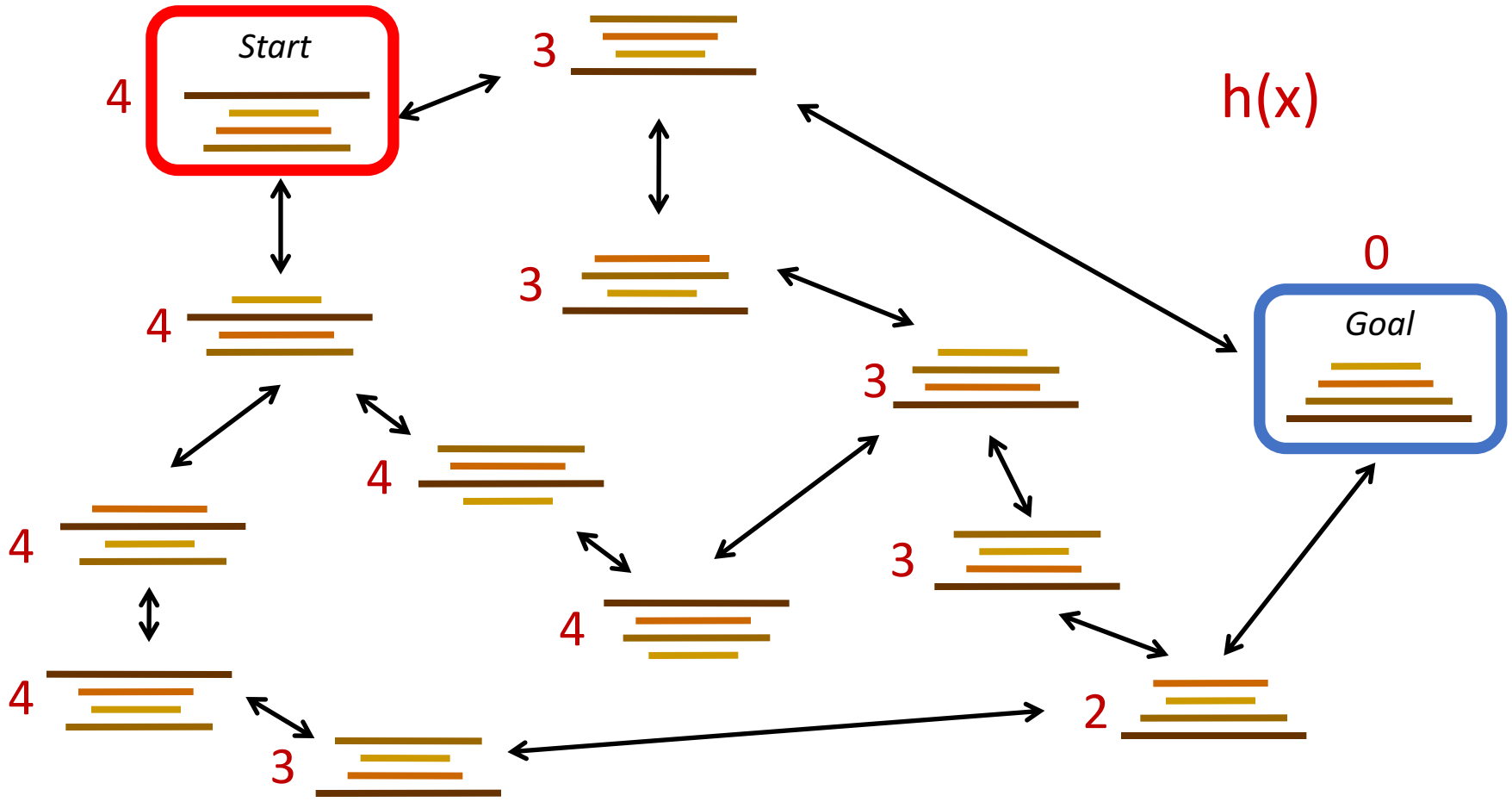
Note that the heuristic is a property of the **state**, **not the action** taken to get to the state!





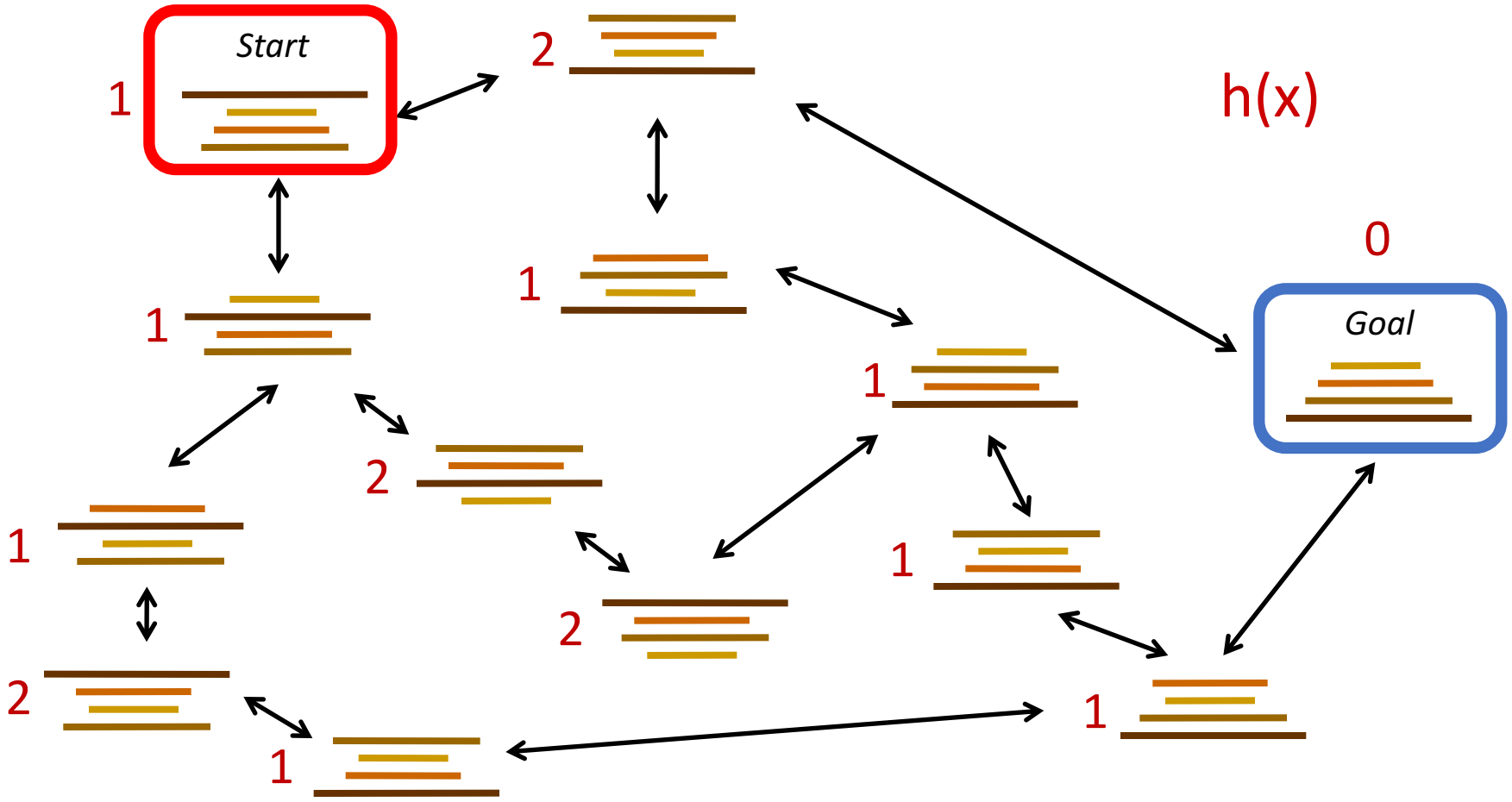
Pancake Heuristics

Heuristic 1: the number of pancakes that are out of place



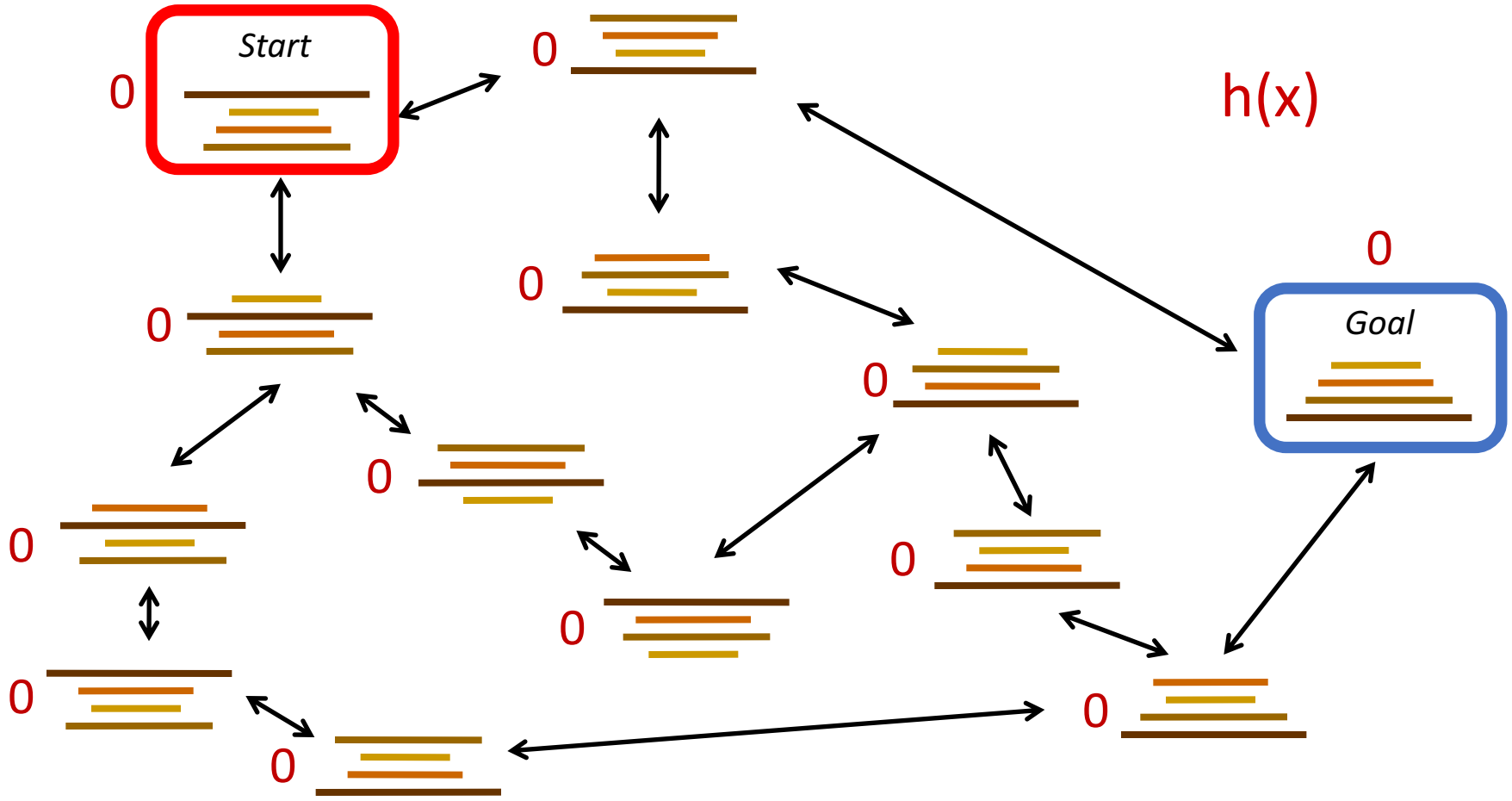
Pancake Heuristics

Heuristic 2: how many pancakes are on top of a smaller pancake?

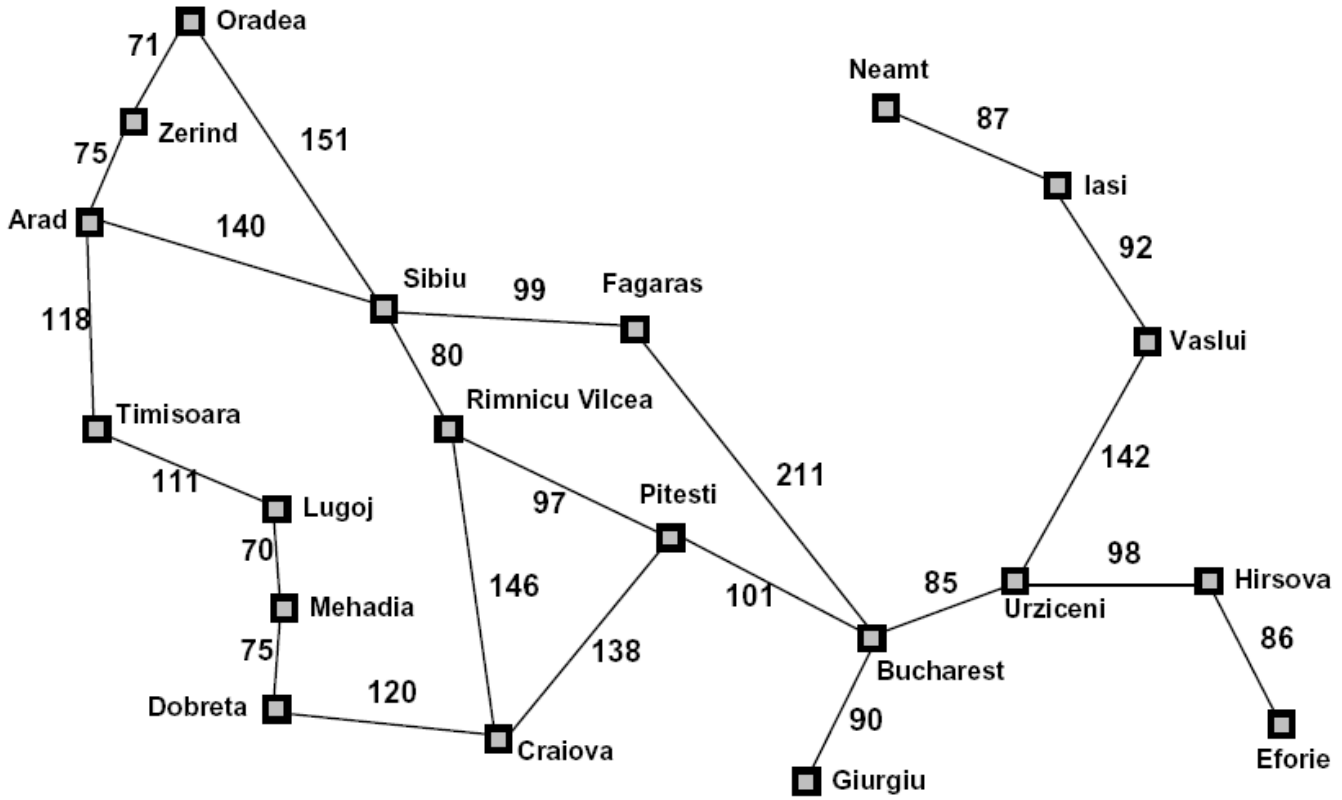


Pancake Heuristics

Heuristic 3: All zeros (aka *null heuristic*, or "I like waffles better anyway")



Straight-line Heuristic in Romania



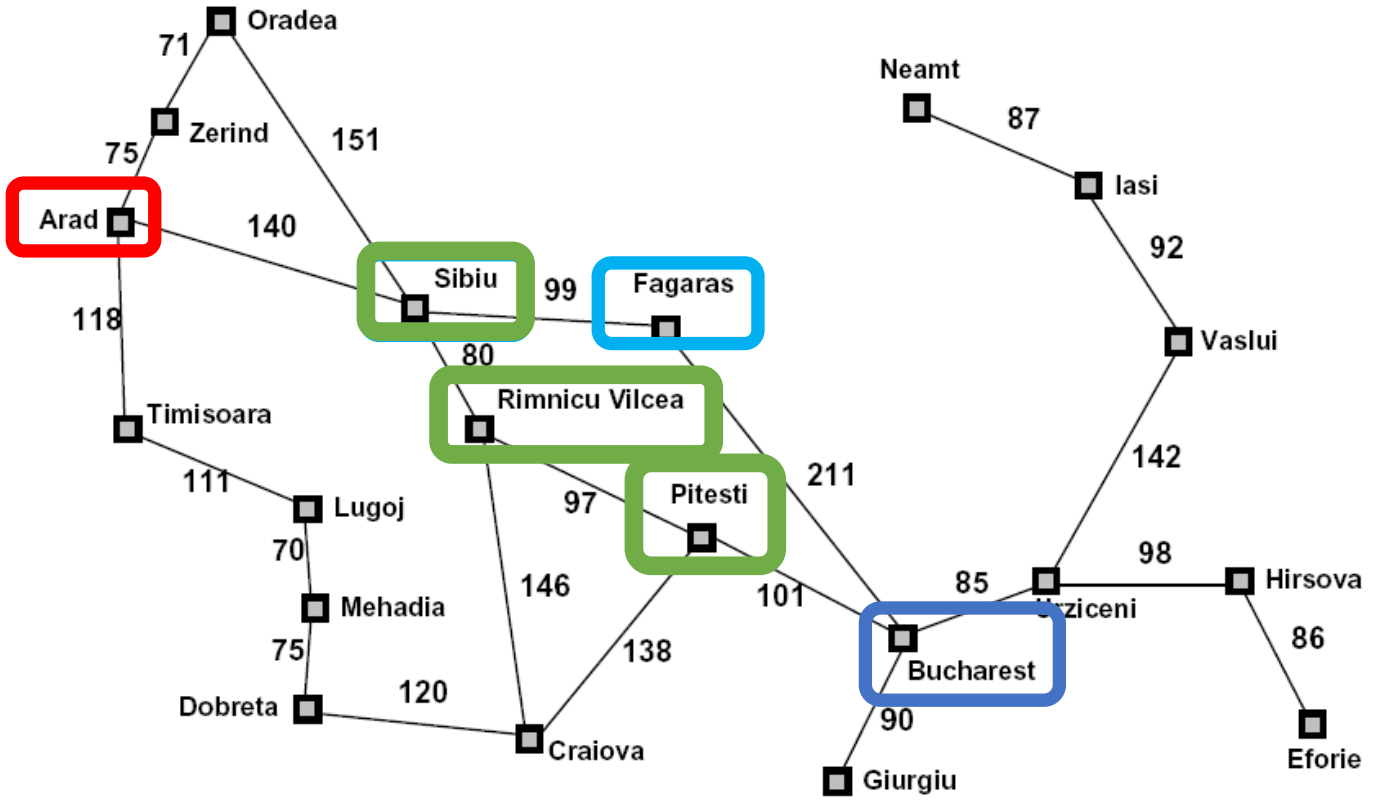
Straight−line distance to Bucharest	
Arad	366
Bucharest	0
Craiova	160
Dobreta	242
Eforie	161
Fagaras	178
Giurgiu	77
Hirsova	151
Iasi	226
Lugoj	244
Mehadia	241
Neamt	234
Oradea	380
Pitesti	98
Rimnicu Vilcea	193
Sibiu	253
Timisoara	329
Urziceni	80
Vaslui	199
Zerind	374

h(x)

Greedy Search

Greedy Straight-Line Search in Romania

- Expand the node that seems closest…



Straight–line distance to Bucharest	
Arad	366
Bucharest	0
Craiova	160
Dobreta	242
Eforie	161
Fagaras	178
Giurgiu	77
Hirsova	151
Iasi	226
Lugoj	244
Mehadia	241
Neamt	234
Oradea	380
Pitesti	98
Rimnicu Vilcea	193
Sibiu	253
Timisoara	329
Urziceni	80
Vaslui	199
Zerind	374

h(x)

Greedy

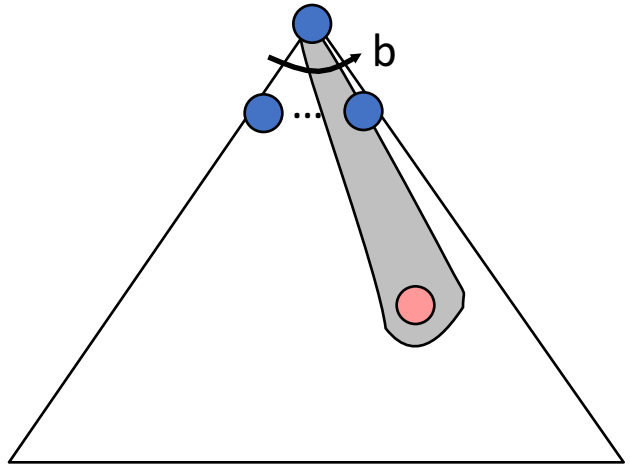
- Cost: 450

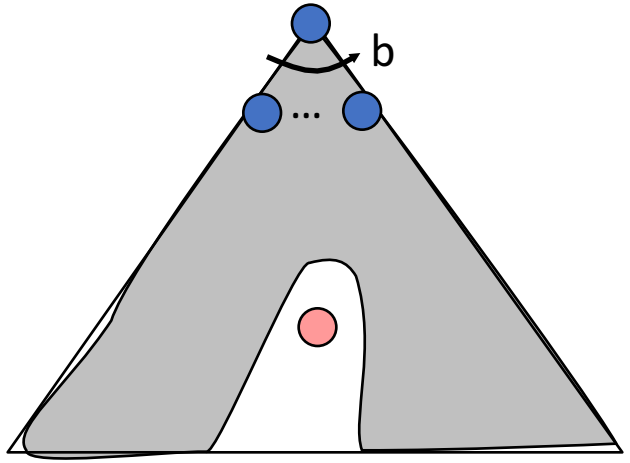
Optimal

- Cost: 418

Greedy Search

- Strategy: expand a node that you think is closest to a goal state
  - Heuristic: estimate of distance to nearest goal for each state
- A common case:
  - Best-first takes you straight to the (non-optimal) goal
- Worst-case: like a badly-guided DFS
- What goes wrong?
  - Doesn't take real path cost into account





Next class

A* search