COMP219: Artificial Intelligence

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COMP219: Artificial Intelligence

Lecture 6: Search Strategies

Overview

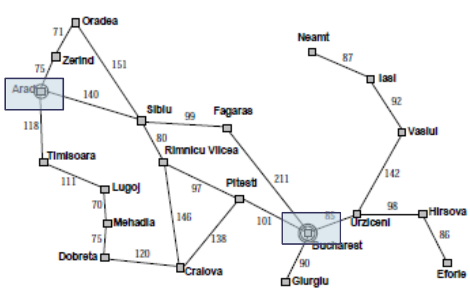
- Last time
  - basic ideas about problem solving
  - state space
  - solutions as paths
  - the notion of solution cost
  - the importance of using the correct level of abstraction
- Today
  - Automating Search
    - Blind (uninformed, brute force) strategies

Problem Solving as Search

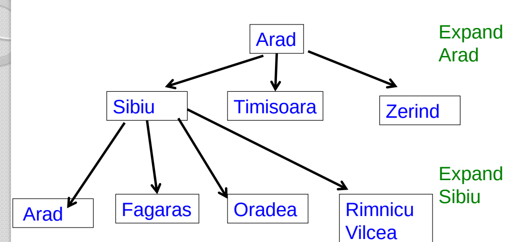
- In the state space view of the world, finding a solution is finding a path through the state space
- When we (as humans) solve a problem like the 8-puzzle we have some idea of what constitutes the next best move
- It is hard to program this kind of approach
- Instead we start by programming the kind of repetitive task that computers are good at
- A *brute force* approach to problem solving involves exhaustively searching through the space of all possible action sequences to find one that achieves the goal

Example: Romania Problem

Travel from Arad to Bucharest



The Search Tree



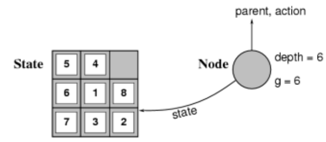
Search strategy: how do we choose which node to expand?

Search Tree Exploration

- The tree is built by taking the initial state and identifying the states that can be obtained by a single application of the operators available
- These new states become the *children* of the initial state in the tree
- These new states are then examined to see if they are the goal state
- If not, the process is repeated on the new states
- We can formalise this description by giving an algorithm for it
- We have different algorithms for different choices of nodes to expand

Implementation: States vs. Nodes

- A state is a (representation of) a physical configuration
- A node is a data structure constituting part of a search tree that includes state, parent node, action, path cost *g(x)*, depth



- Expanding the tree creates new nodes, filling in the various fields and creating the corresponding states

General Algorithm for Search

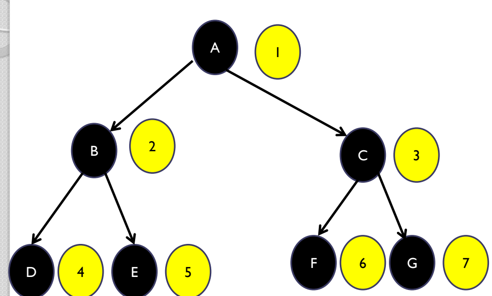
```
agenda = initial state;
while agenda not empty do
  pick node from agenda;
  new nodes = apply operations to state;
  if goal state in new nodes then
      return solution;
  else add new nodes to agenda;
```

- Question: How to pick states for expansion?
- Two obvious strategies
  - depth first search
  - breadth first search

Breadth First Search

- Start by expanding initial state - gives tree of depth 1
- Then expand all nodes that resulted from previous step
  - gives tree of depth 2
- Then expand all nodes that resulted from previous step, and so on
- Expand all nodes at depth *n* before going to level *n* + 1

Breadth First Search



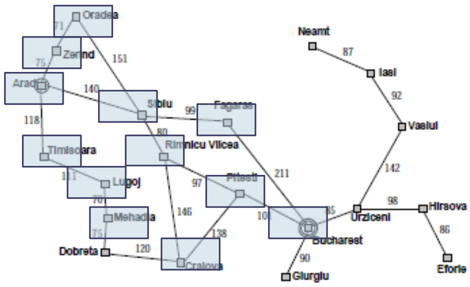
General Breadth First Search

```
/* Breadth first search */
agenda = initial state;
while agenda not empty do
  pick node from front of agenda;
  new nodes = apply operations to
 state;
  if goal state in new nodes then
     return solution;
 else APPEND new nodes to END of agenda
```

Example: Romania BFS

Travel from Arad to Bucharest

D= 0 | D= 1 | D= 2 | D= 3



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Properties of Breadth First Search

- Advantage: *guaranteed* to reach a solution if one exists
- Finds the shortest (cheapest, best) solution in terms of the number of operations applied to reach a solution
- Disadvantage: time taken to reach solution
  - Let *b* be branching factor - maximum number of operations that may be performed from any level
  - If solution occurs at depth *d*, then we will look at $1 + b + b^2 + \cdots + b^d$ nodes before reaching solution - exponential
  - The memory requirement is b^d

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Complexity

Depth	Nodes	Time
2	110	0.11 msec
4	11,110	11 msec
6	10^6	1.1 sec
8	10^8	2 mins
10	10^{10}	3 hours
12	10^{12}	13 days
14	10^{14}	3.5 years
16	10^{16}	350 years

Time for BFS assuming a branching factor of 10 and 1 million nodes expanded per second

Combinatorial Explosion !!

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Depth First Search

- Start by expanding initial state
- Pick one of nodes resulting from 1st step, and expand it
- Pick one of nodes resulting from 2nd step, and expand it, and so on
- Always expand *deepest node*
- Follow one "branch" of search tree

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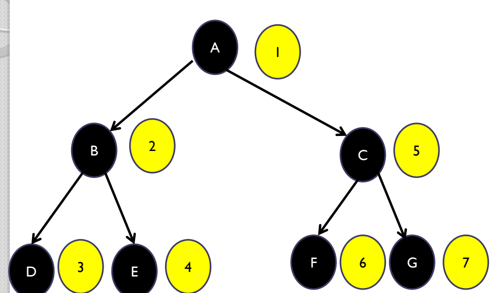
Depth First Search



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General Depth First Search

```
/* Depth first search */
agenda = initial state;
  while agenda not empty do
  pick node from front of agenda;
  new nodes = apply operations to
 state;
  if goal state in new nodes then
     return solution;
  else put new nodes on FRONT of
 agenda;
```

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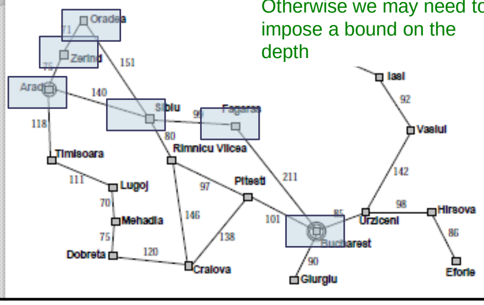
Example: Romania DFS

Travel from Arad to Bucharest

OK when all roads lead to Bucharest

Otherwise we may need to impose a bound on the depth



Properties of Depth First Search

- Depth first search is guaranteed to find a solution if one exists, unless there are infinite paths
- Solution found is not guaranteed to be the best
- The amount of time taken is usually much less than breadth first search
- Memory requirement is always much less than breadth first search
- For branching factor *b* and maximum depth of the search tree *d*, depth-first search requires the storage of only *bd* nodes
- Bounded Depth First Search: Impose a depth limit to avoid long (infinite) paths without a solution – but then it is not guaranteed to find a solution (may exist beyond depth bound)

Summary: Basic Search Strategies

- Breadth-first search is complete but expensive
- Depth-first search is cheap but incomplete
- Can't we do better than this?

- Next time
  - Improving on blind search