COMP210: Artificial Intelligence

Lecture 7. Combining strategies and speeding up

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- Last Week
  - Basic problem solving techniques:
    - **Breadth-first search**
    - complete but expensive.
    - **Depth-first search**
    - cheap but incomplete
- Today
  - Variations and combinations:
    - **Limited depth search**
    - **Iterative deepening search**
  - Speeding up techniques
    - Avoiding repetitive states
    - Bi-directional search

Depth Limited Search

- Depth first search has some desirable properties — space complexity.
- But if wrong branch expanded (with no solution on it), then it may not terminate.
- Idea: introduce a depth limit on branches to be expanded.
- Don’t expand a branch below this depth.
- Most useful if you know the maximum depth of the solution.

Depth Limited Search

```
depth limit = max depth to search to;
agenda = initial state;
   if initial state is goal state then return
  solution
   else
      while agenda not empty do
      take node from front of agenda;
      if depth(node) < depth limit then
         {new nodes = apply operations to node;
         add new nodes to front of agenda;
         if goal state in new nodes then return
           solution;}
```

Example: Romania Problem

Only 20 cities on the map so no path longer than 19
In fact any city can reach any other in no more than 10 steps.

Max depth = 3

Can’t find Eforie with Max depth = 3; Max depth = 9 would find all cities, but use some bad routes

Depth Limited Search

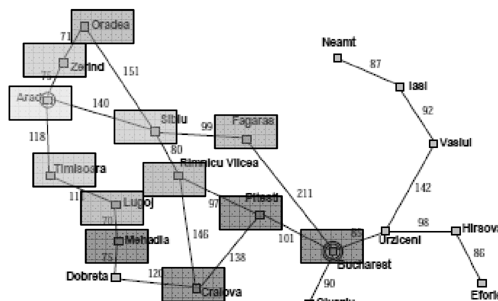
- Will always terminate
- Will find solution if there is one in the depth bound
- Too small a depth bound misses solutions
- Too large a depth bound may find poor solutions when there are better ones

Iterative Deepening

- Problem with choosing depth bound; incomplete or admits poor siolutions
- Iterative deepening a variation which is complete and find best solution
- Basic idea is:
  - do d.l.s. for depth n = 0; if solution found, return it;
  - otherwise do d.l.s. for depth n = n + 1; if solution found, return it, etc;
  - So we repeat d.l.s. for all depths until solution found.
- Useful if the search space is large and the maximum depth of the solution is not known.

Example: Romania Problem

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



General Algorithm for Iterative Deepening

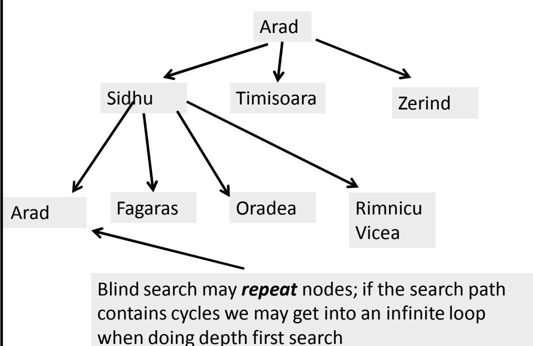
```
depth limit = 0;
  repeat
  { result = depth_limited_search
      (max depth = depth limit;
       agenda = initial node; );
       if result contains goal then
         return result;
    depth limit = depth limit + 1;}
  until false; /* i.e., forever */
```

- Calls d.l.s. as subroutine.

IDS Properties

- Note that in iterative deepening, we re-generate nodes
- on the fly.
- Each time we do call on depth limited search for depth d, we need to regenerate the tree to depth d − 1.
- Trade off time for memory.
- In general we might take a little more time, but we save
- a lot of memory.
  - Example: Suppose b = 10 and d = 5.
  - Breadth first search would require examining 111, 111 nodes, with memory requirement of 100, 000 nodes.
  - Iterative deepening for same problem: 123, 456 nodes to be searched, with memory requirement only 50 nodes.
  - Takes 11% longer in this case, but savings on memory are immense

The Search Tree



Blind search may ***repeat*** nodes; if the search path contains cycles we may get into an infinite loop when doing depth first search

Avoiding Repeated States

- There are three ways to deal with this (in order of increasing effectiveness and computational overhead):
  - do not return to the state you have just come from;
  - do not create paths with cycles in them;
  - do not generate any state that was ever generated before.
- Note there is a trade off between the cost of extra search and the cost of checking for repeated states.

Branching

- In analyses branching is often assumed to be uniform
- But in practice this is often not so
- This can make a big difference to the search space

Blocks World

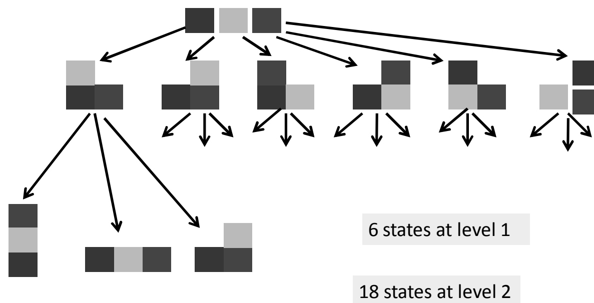
Move any ***clear*** block to another ***clear*** block

Move any block to the table

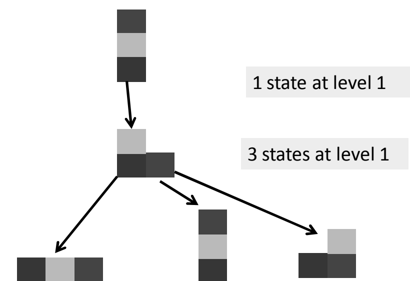
Initial

Goal

Search Space for Initial to Goal



Search Space for Goal to Initial



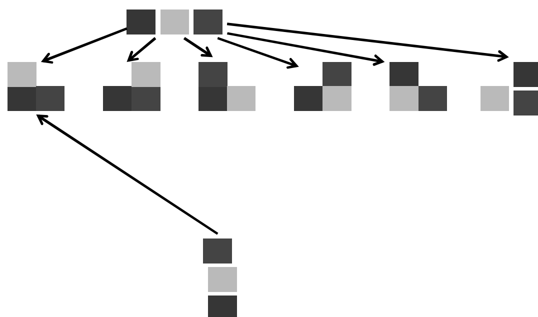
Goal vs Data driven search

- We can chose to search from initial state to the goal (data driven)
- Or from the goal to the initial state (goal driven)
- The branching may be very different which will affect the search
- Goal driven search is very often very much more efficient (few paths reach the goal)
- Often used in expert systems (and Prolog)

Bi directional search

- If we are unsure the searching from both ends may be the best

Bidirectional Search



Bi-directional Search: Good

- Much more efficient.
- Rather than doing one search of bd, we do *two bd/2* searches.
  - Example:
    - Suppose b = 10, d = 6.
    - Breadth first search will examine 10^6 = 1, 000, 000 nodes.
    - Bidirectional search will examine 2×10^3 = 2, 000 nodes.
- Can combine different search strategies in different directions.

Bi-directional Search: Bad

- Must be able to generate predecessors of states.
- There must be an efficient way to check whether each new node appears in the other search.
- For large d, is still impractical!
- For two bi-directional breadth-first searches, with branching factor b and depth of the solution d we have memory requirement of bd/2 for each search.

Today

- More advanced problem solving techniques:
  - Depth limited search
  - Iterative deepening
  - Bi-directional search
  - Avoiding repeated states
- These improved on basic techniques like breadth-first and depth-first search.
- However, they still aren’t always powerful enough to give solutions for realistic problems.
- Are there more improvements we can make?
- Next Time
  - Heuristic Search Techniques