Search

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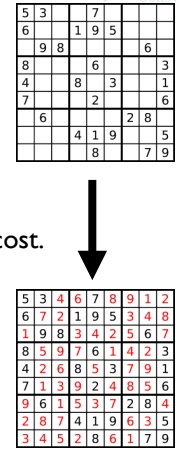
(pictures: Wikipedia)

Search

Basic to problem solving:

- Problem can be in various *states*.
- Start in an *initial state*.
- Have some *actions* available.
- Each action has a *cost*.
- Want to reach some *goal*, minimizing cost.



Happens in simulation.
Not web search.

Formal Definition

Set of states S

Start state $s \in S$

Set of actions A and action rules $a(s) \rightarrow s'$

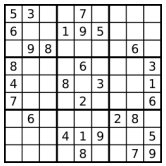
Goal test $g(s) \rightarrow \{0, 1\}$

Cost function $C(s, a, s') \rightarrow \mathbb{R}^+$

So a search problem is specified by a tuple, (S, s, A, g, C).

Example

Sudoku



States: all legal Sudoku boards.

Start state: a particular, partially filled-in, board.

Actions: inserting a number into the board.

Goal test: all cells filled and no collisions.

Cost function: 1 per number.

Example

Flights - e.g., ITA Software.

States: airports.

Start state: RDU.

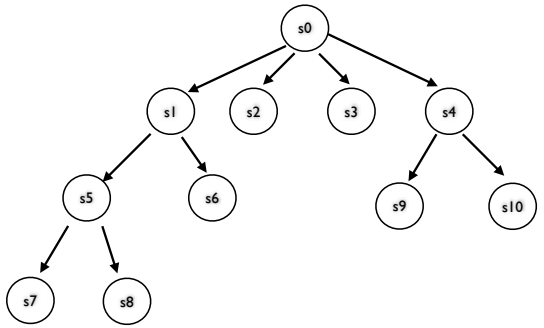
Actions: available flights from each airport.

Goal test: reached Tokyo.

Cost function: time and/or money.

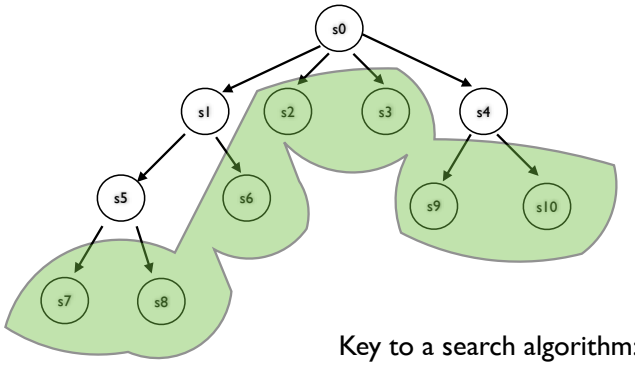
The Search Tree

Classical conceptualization of search.



The Search Tree

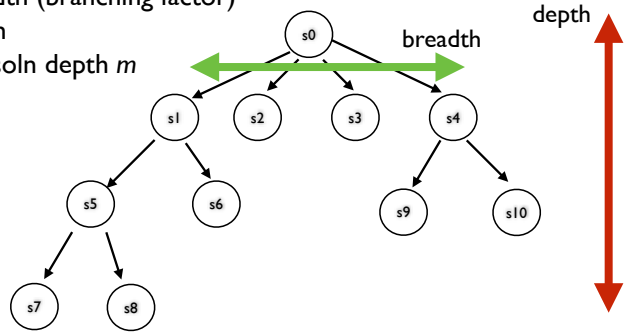
Expand the tree one node at a time.
Frontier: set of nodes *in tree*, but not *expanded*.



Key to a search algorithm:
which node to expand next?

The Search Tree

Important quantities:
breadth (branching factor)
depth
min soln depth *m*



$O(b^d)$ leaves in a search tree of breadth b, depth d.

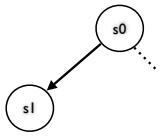
How to Expand?

Uninformed strategy: you know nothing about likely solutions in the tree.

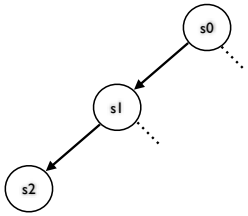
What to do?
- Expand deepest node *(depth-first search)*
- Expand closest node *(breadth-first search)*

Properties
- Completeness
- Optimality
- Time Complexity *(total number of nodes visited)*
- Space Complexity *(size of frontier)*

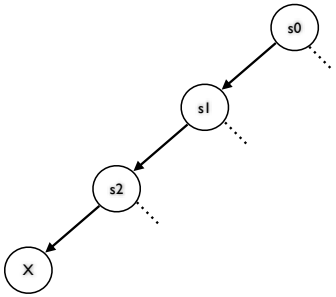
Depth-First Search



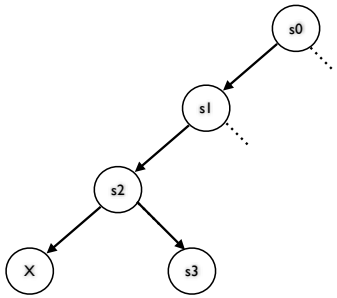
Depth-First Search



Depth-First Search



Depth-First Search



Depth-First Search

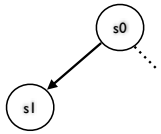
Properties:

- Completeness: Only for finite trees.
- Optimality: No.
- Time Complexity: $O(b^{d+1})$
- Space Complexity: $O(bd)$

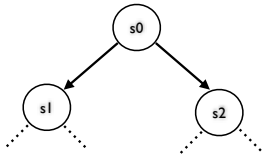
Here *m* is depth of found solution (*not necessarily min solution depth*).

The deepest node happens to be the one you most recently visited - easy to implement recursively OR manage frontier using LIFO queue.

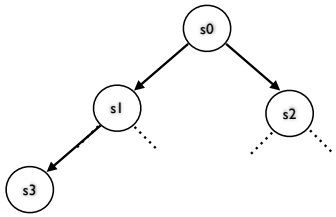
Breadth-First Search



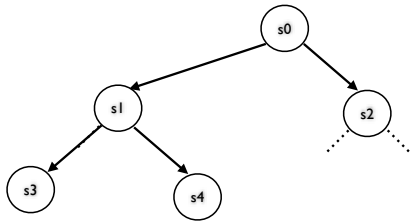
Breadth-First Search



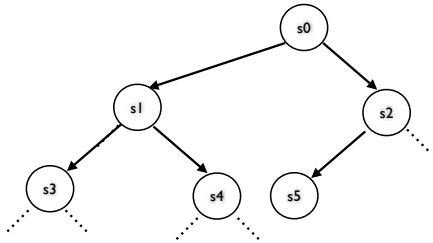
Breadth-First Search



Breadth-First Search



Breadth-First Search



Breadth-First Search

Properties:

- Completeness: Yes.
- Optimality: Yes for constant cost.
- Time Complexity: $O(b^{m+1})$
- Space Complexity: $O(b^{m+1})$

Better than depth-first search in all respects except *memory cost* - must maintain a large frontier.

Manage frontier using FIFO queue.

Iterative Deepening Search

Combine these two strengths.

The core problems in DFS are a) *not optimal*, and b) *not complete*. In both cases, because it fails to explore other alternatives.

Iterative Deepening:
- Run DFS to a fixed depth z.
- Start at z=*1*. If no solution, increment z and rerun.

IDS

Optimal for constant cost! Proof?

How can that be a good idea?
It duplicates work.

Sure but:
- Low memory requirement (equal to DFS).
- Not many more nodes expanded than BFS. (About twice as many for binary tree.)

IDS

Key Insight:
- Many more nodes at depth *m+1* than at depth *m*.

MAGIC.

"In general, iterative deepening search is the preferred uninformed search method when the state space is large and the depth of the solution is unknown." (R&N)

Friday

Informed searches … what if you know something about the the solution? What form should such knowledge take? How should you use it?

Ponder.