State space search

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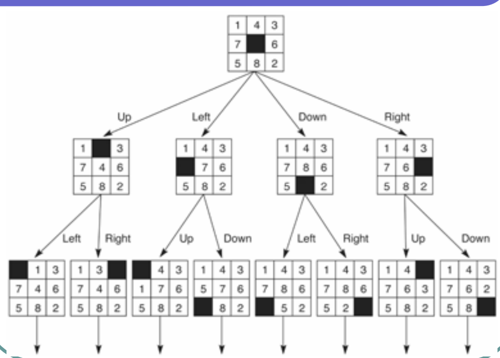
State Space Search

- Define problem in form of a state space and use a search algorithm to find a solution
- The problem space consists of:
  - a *state space* which is a set of states representing the possible configurations of the world
  - a set of *operators* which can change one state into another
- The problem space can be viewed as a graph where the states are the nodes and the arcs represent the operators.

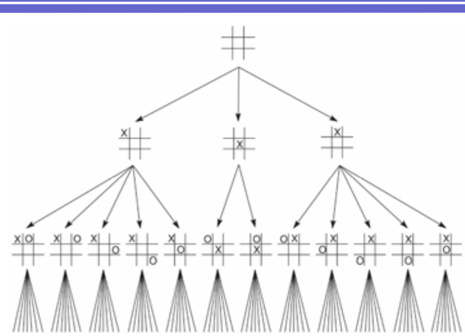
State space of the 8-puzzle



Size of search space: 8/16-puzzle

- 8-puzzle: 8! = 40,320 different states
- 16-puzzle: 16! =20,922,789,888,000 ≈ 10^{13} different states
- Game works by moving tiles
- Simplification: assume only blank tile is moved
- Legal moves: blank up, down, left, right
- Keep blank tile on board
- State space consists of two disconnected subgraphs

State space of tic-tac-toe



Size of search space: tic-tac-toe

- Start is empty board
- Goal is board with 3 Xs in a row, column or diagonal
- Path from start to end gives a series of moves in a winning game
- Vocabulary is (blank, X, O)
- 3^9 = 19,683 ways to arrange (blank, X, O) in 9 spaces
- No cycles possible: why?
- Represented as DAG (directed acyclic graph)
- 9! = 362,880 different paths can be generated: why?

Search Strategies

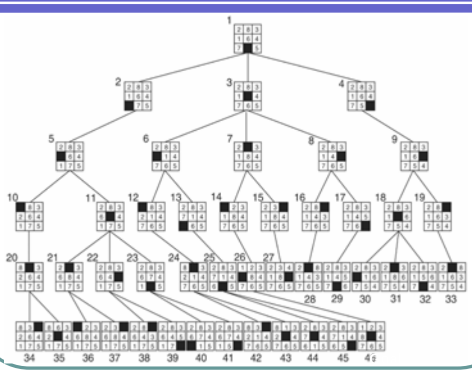
- Traverse the graph from an initial state to find a goal
- Alternative search strategies:
  - Depth-first: visit children before siblings (= alg. backtrack)
  - Breadth-first: visit graph level-by-level
  - Best-first: order unvisited nodes through heuristic, finding best candidate for next step

Breadth-First search

```
function breadth_first_search;

begin
  open := [Start];                                              % initialize
  closed := [ ];
  while open ≠ [ ] do                                           % states remain
    begin
      remove leftmost state from open, call it X;
        if X is a goal then return SUCCESS                      % goal found
          else begin
            generate children of X;
            put X on closed;
            discard children of X if already on open or closed;  % loop check
            put remaining children on right end of open          % queue
          end
    end
  return FAIL                                                   % no states left
end.
```

Breadth-first search of the 8-puzzle



Quiz 1

- Write a program to print out solutions for the 8-puzzle game using the BFS algorithm.
- Question to solve:
  - How to represent a state of 8-puzzle game in memory?
  - How to compare two states?
  - How to generate sub-states from a state?
  - How to store states in two collections (open and closed)?
  - How to print a state in the screen?

Depth first search

```
begin
  open := [Start];                                              % initialize
  closed := [ ];
  while open ≠ [ ] do                                           % states remain
    begin
      remove leftmost state from open, call it X;
      if X is a goal then return SUCCESS                        % goal found
        else begin
          generate children of X;
          put X on closed;
          discard children of X if already on open or closed;    % loop check
          put remaining children on left end of open             % stack
        end
    end;
  return FAIL                                                   % no states left
end.
```

Depth-first vs. breadth-first

- Breadth-first:
  - always finds shortest path
  - inefficient if branching factor **B** is very high
  - memory requirements high
  - exponential space for states required: $\mathbf{B}^n$
- Depth-first:
  - does not always find shortest path
  - efficient if solution path is known to be long
  - but can get „lost“ in (infinitely) deep paths
  - only memory for states of one path needed: $\mathbf{B} \times n$

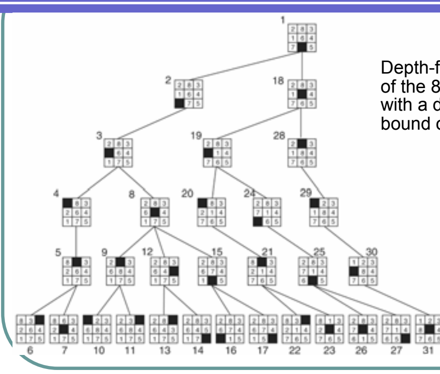
Iterative Deepening

Compromise solution:

- use depth-first search, but
- with a maximum depth before going to next level

→ *Depth-first Iterative Deepening*

Depth-first search of the 8-puzzle



Depth-first search of the 8-puzzle with a depth bound of 5

Quiz 2

- Rewrite the program in Quiz 1 using the DFS algorithm.
- Compare the solution given by the two strategies.