AI 2002
Artificial Intelligence

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Terminologies

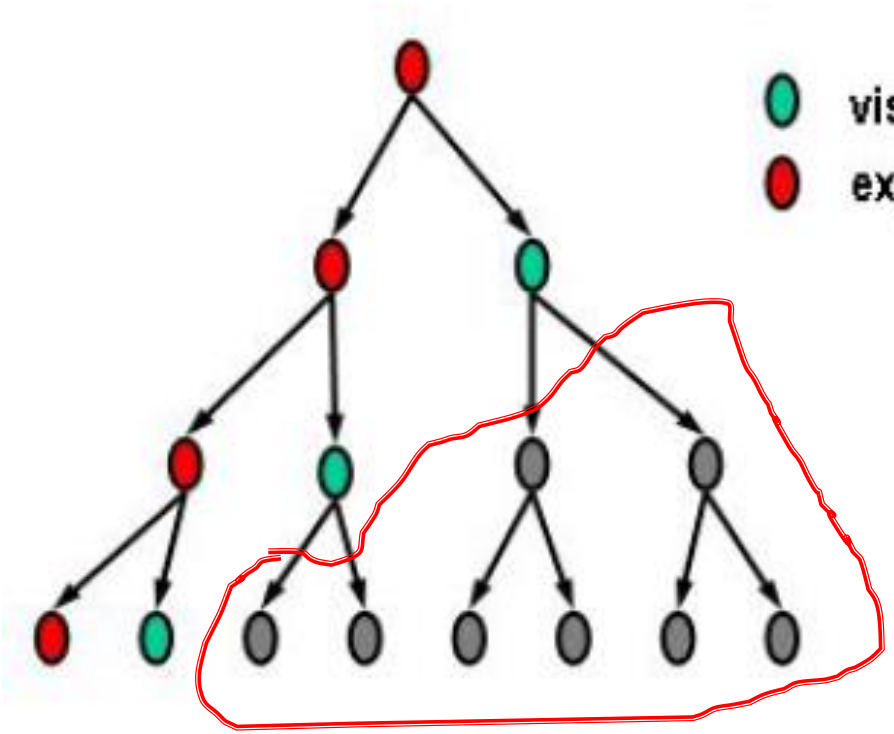
Visited (Open) List:

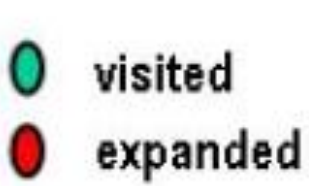
- The *set of all leaf nodes available for expansion* at any given point is called the open list, (may be referred as **frontier**).
- In general, a state is said to be visited if it has ever shown up in search a node.
- The intuition is that ***we have visited*** them, but ***we have not generated its descendants***.

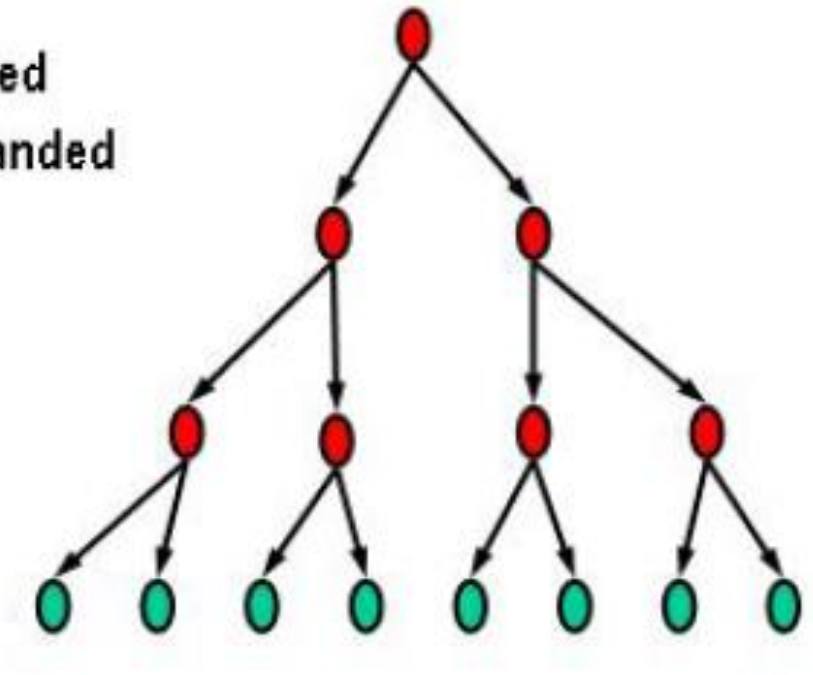
Expanded (Closed, Explored) List:

- *Algorithms that forget their history are doomed to repeat it.*
- The way to avoid exploring redundant paths is to remember where one has been.
- To do this, we design **explored set** (also known as the **closed list**), which remembers every expanded node.

Terminologies







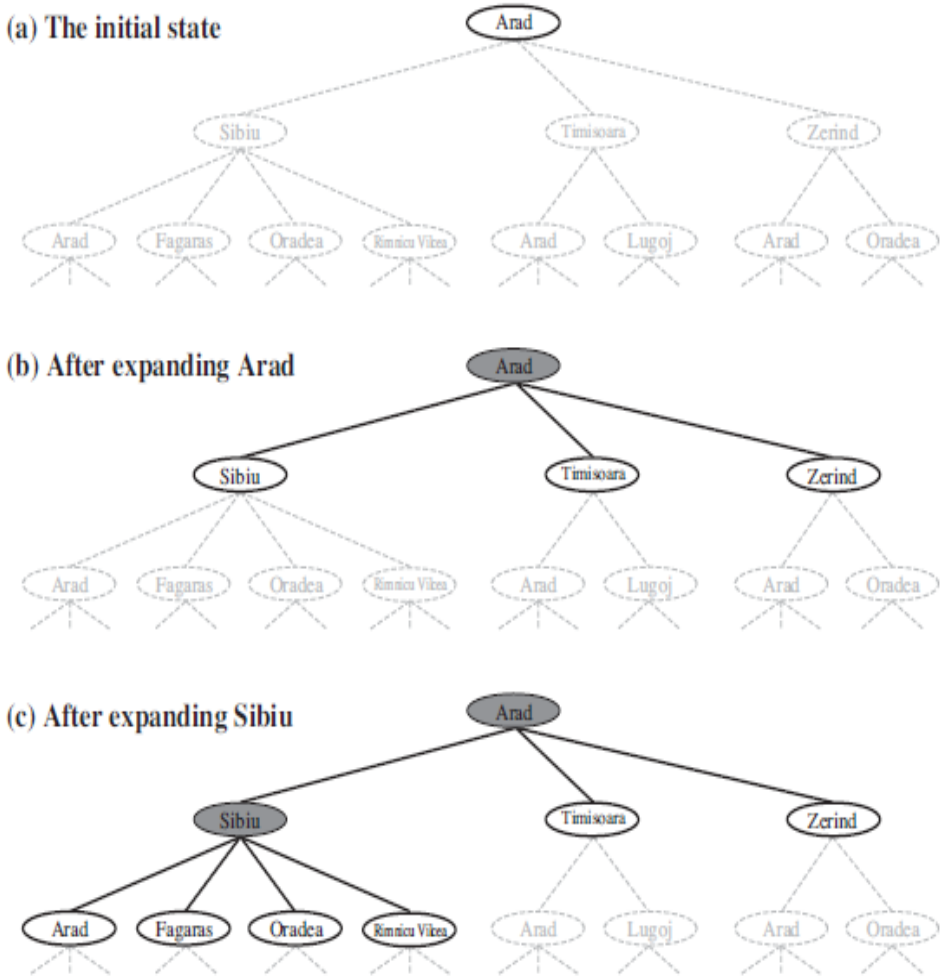
Depth First Search

Breadth First Search

Terminologies

Partial search trees for finding a route from Arad to Bucharest.

- Nodes that have been **visited but not yet expanded** are outlined in **bold**;
- Nodes that have been **expanded are shaded**;
- Nodes that have **not been visited** are shown in faint dashed lines.



Uninformed Search

Uninformed Search

- **Uninformed search** also called **blind search**
- The strategies have **no additional information** about the states beyond that provided in the problem definition.
- ***Use the information only provided*** in the problem definition.
  - Breadth-first search
  - Depth-first search
    - Depth-limited search
    - Iterative deepening search
  - Uniform cost search
  - Bidirectional search

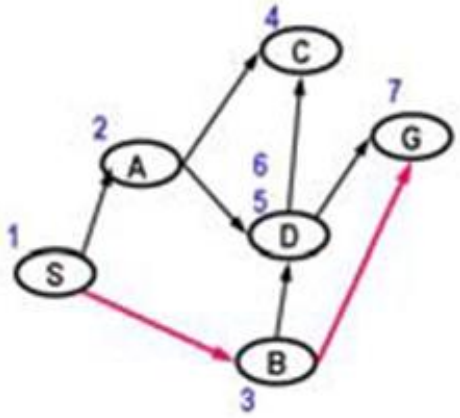
Breadth-First Search

Breadth-First Search

Breadth-First (without Visited list)

Pick first element of Q; Add path extensions to end of Q

	Q
1	(S)
2	(A S) (B S)
3	(B S) (C A S) (D A S)
4	(C A S) (D A S) (D B S) (G B S)*
5	(D A S) (D B S) (G B S)
6	(D B S) (G B S) (C D A S) (G D A S)
7	(G B S) (C D A S) (G D A S) (C D B S) (G D B S)



Added paths in blue

We show the paths in reversed order; the node's state is the first entry.

* We could have stopped here, when the first path to the goal was visited

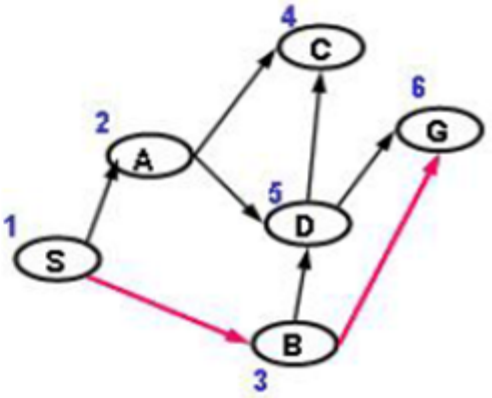
When we need the final path, we have to continue till the goal state is expanded.

Breadth-First Search

Breadth-First

Pick first element of Q; Add path extensions to end of Q

	Q	Visited	Expanded
1	(S)	S	S
2	(A S) (B S)	A,B,S	A,S
3	(B S) (C A S) (D A S)	C,D,B,A,S	B,A,S
4	(C A S) (D A S) (G B S)*	G,C,D,B,A,S	C,B,A,S
5	(D A S) (G B S)	G,C,D,B,A,S	D,C,B,A,S
6	(G B S)	G,C,D,B,A,S	G,D,C,B,A,S



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We show the paths in reversed order; the node's state is the first entry.

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When we need the final path, we have to continue till the goal state is expanded.

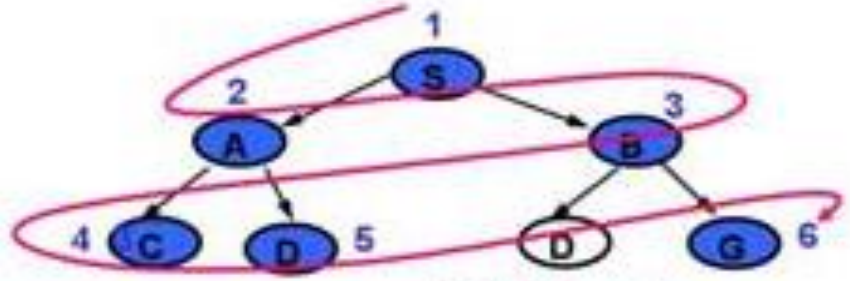
Traversal = S, A, B, C, D, G

The Final path = S, B, G

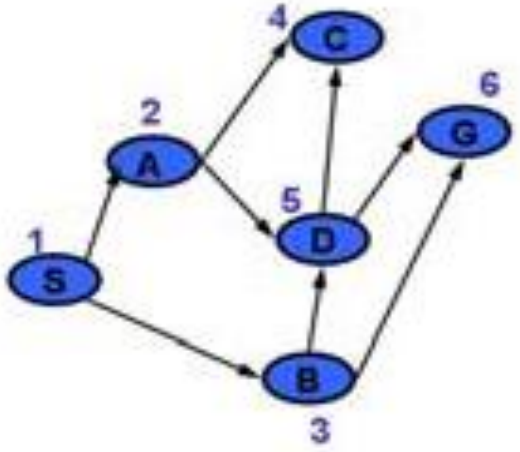
Breadth-First Search

Breadth-First

Another (easier?) way to see it



NB: D is not visited again



Numbers indicate order pulled off of Q (expanded)

Dark blue fill = Visited & Expanded
Light gray fill = Visited

Breadth-First Search

Completeness: Yes, (if b is finite)

Time complexity: Imagine ***searching a uniform tree*** where every state has b successors.

- The root of the search tree generates b nodes at the first level, each of which generates b more nodes,
- for a total of b^2 at the second level, yielding b^3 nodes at the third level, and so on. Now suppose that the solution is at depth d

$$b + b^2 + b^3 + \cdots + b^d = O(b^d)$$

- If the algorithm were to apply the **goal test** to nodes when selected for **expansion**, rather than when visited,
  - the whole *layer of nodes at depth d would be expanded before the goal was detected* and
  - the time complexity would be $\boldsymbol{O(b^{d+1})}$.

Breadth-First Search

Space complexity: For breadth-first graph search in particular, every node generated remains in memory.

- There will be $\boldsymbol{O(b^{d-1})}$ nodes in the explored set
- $\boldsymbol{O(b^{d})}$ nodes in the frontier,

Optimality: Yes, if the cost = 1 per step

*The **memory requirement** is a bigger problem for breadth-first search than the execution time.*

Breadth-First Search

Depth	Nodes	Time	Memory
2	110	.11 milliseconds	107 kilobytes
4	11,110	11 milliseconds	10.6 megabytes
6	10^6	1.1 seconds	1 gigabyte
8	10^8	2 minutes	103 gigabytes
10	10^{10}	3 hours	10 terabytes
12	10^{12}	13 days	1 petabyte
14	10^{14}	3.5 years	99 petabytes
16	10^{16}	350 years	10 exabytes

Time and memory requirements for breadth-first search. The numbers shown assume branching factor $b = 10$; 1 million nodes/second; 1000 bytes/node.

Breadth-First Search

- The root node is expanded by **first-in-first-out (FIFO), Queue data structure.**
- **Complete**: find the solution eventually
- **Optimal**: if the step cost is 1

Disadvantages:

- The branching factor of a node is large,
- The **space complexity and time complexity** are enormous for even small instances (e.g., chess)

Reading Material

- **Artificial Intelligence,** A Modern Approach

  Stuart J. Russell and Peter Norvig

  - **Chapter 3.**