Uninformed Search

Computer Science cpsc322, Lecture 5

(Textbook Chpt 3.5)

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Recap

- Search is a key computational mechanism in many AI agents
- We will study the basic principles of search on the simple **deterministic planning agent model**

Generic search approach:

- define a search space graph,
- start from current state,
- incrementally explore paths from current state until goal state is reached.

Searching: Graph Search Algorithm with three bugs ☹

Input: a graph,
a start node,
Boolean procedure *goal(n)* that tests if *n* is a goal node.

frontier := { ⟨*g*⟩: *g* is a goal node }; ← should be initiated with start node

while *frontier* is not empty:

  select and **remove** path ⟨$n_0, n_1, \ldots, n_k$⟩ from *frontier*;

  if *goal*(n_k)

    return ⟨n_k⟩ ; ← should return the path

  for every neighbor *n* of n_k

    add ⟨$n_0, n_1, \ldots, n_k$ n⟩ to *frontier*;

end while

- The *goal* function defines what is a solution.
- The *neighbor* relationship defines the graph.
- Which path is selected from the frontier defines the search strategy.

Lecture Overview

- Recap
- Criteria to compare Search Strategies
- Simple (Uninformed) Search Strategies
  - Depth First
  - Breadth First

start playing with AIspace

Comparing Searching Algorithms: will it find a solution? the best one?

Def. (complete): A search algorithm is complete if, whenever at least one solution exists, the algorithm **is guaranteed to find a solution** within a finite amount of time.

Def. (optimal): A search algorithm is optimal if, when it finds a solution , it is the best solution

Comparing Searching Algorithms: Complexity

Def. (time complexity)

The time complexity of a search algorithm is an expression for the **worst-case** amount of time it will take to run,

- expressed in terms of the **maximum path length** ***m*** and the **maximum branching factor** ***b***.

Def. (space complexity) : The space complexity of a search algorithm is an expression for the **worst-case** amount of memory that the algorithm will use (*number of nodes*),

- Also expressed in terms of ***m* and *b***.

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Depth-first Search: DFS

- **Depth-first search** treats the frontier as a **stack**
- It always selects one of the last elements added to the frontier.

Example:

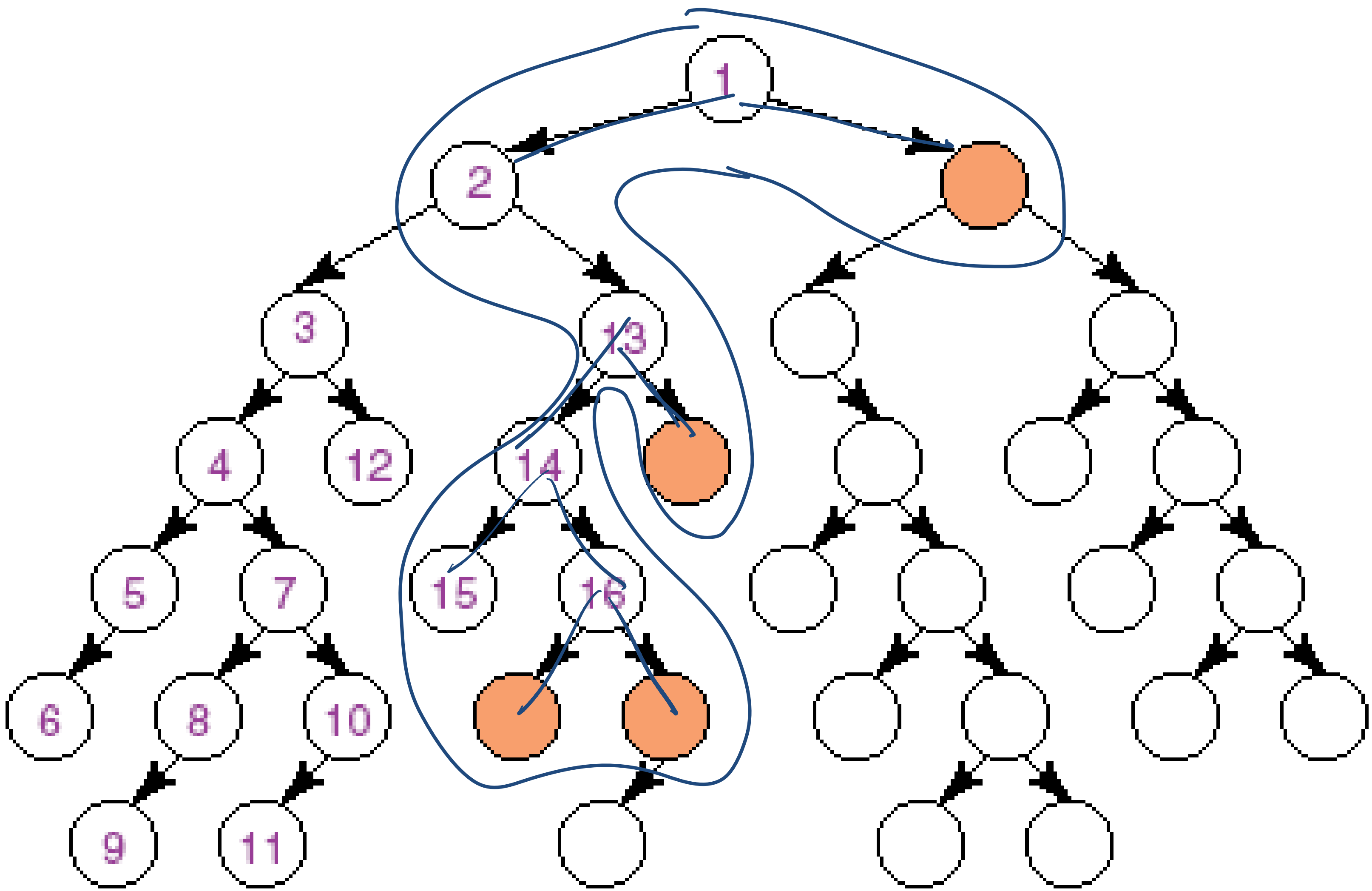
push *pop*

order in which these are added is not specified in pure DFS

- the frontier is $[p_1, p_2, \ldots, p_r]$
- neighbors of last node of p_1 (its end) are $\{n_1, \ldots, n_k\}$

- What happens?
  - p_1 is selected, and its end is tested for being a goal. *If not...*
  - New paths are created attaching $\{n_1, \ldots, n_k\}$ to p_1
  - These "replace" p_1 at the beginning of the frontier. *K new paths*
  - Thus, the frontier is now $[(p_1, n_1), \ldots, (p_1, n_k), p_2, \ldots, p_r]$.
  - *NOTE:* p_2 is only selected when all paths extending p_1 have been explored.

Depth-first search: Illustrative Graph --- Depth-first Search Frontier



Depth-first Search: Analysis of DFS

- Is DFS complete?
  - Depth-first search isn't guaranteed to halt on graphs with cycles.
  - However, DFS ***is*** complete for finite acyclic graphs.
- Is DFS optimal?
- What is the time complexity, if the maximum path length is *m* and the maximum branching factor is *b* ?
  - The time complexity is ? ?: must examine every node in the tree.
  - Search is unconstrained by the goal until it happens to stumble on the goal.
- What is the *space complexity*?
  - Space complexity is ? ? the longest possible path is *m*, and for every node in that path must maintain a fringe of size *b*.

Depth-first Search: When it is appropriate?

Appropriate

- Space is restricted (complex state representation e.g., robotics)
- There are many solutions, perhaps with long path lengths, particularly for the case in which all paths lead to a solution

AIspace

Inappropriate

- Cycles
- There are shallow solutions
- if you care about optimality!

Why DFS need to be studied and understood?

- It is simple enough to allow you to learn the basic aspects of searching (When compared with breadth first)

- It is the basis for a number of more sophisticated / useful search algorithms

Lecture Overview

- Recap
- Simple (Uninformed) Search Strategies
  - Depth First
  - Breadth First

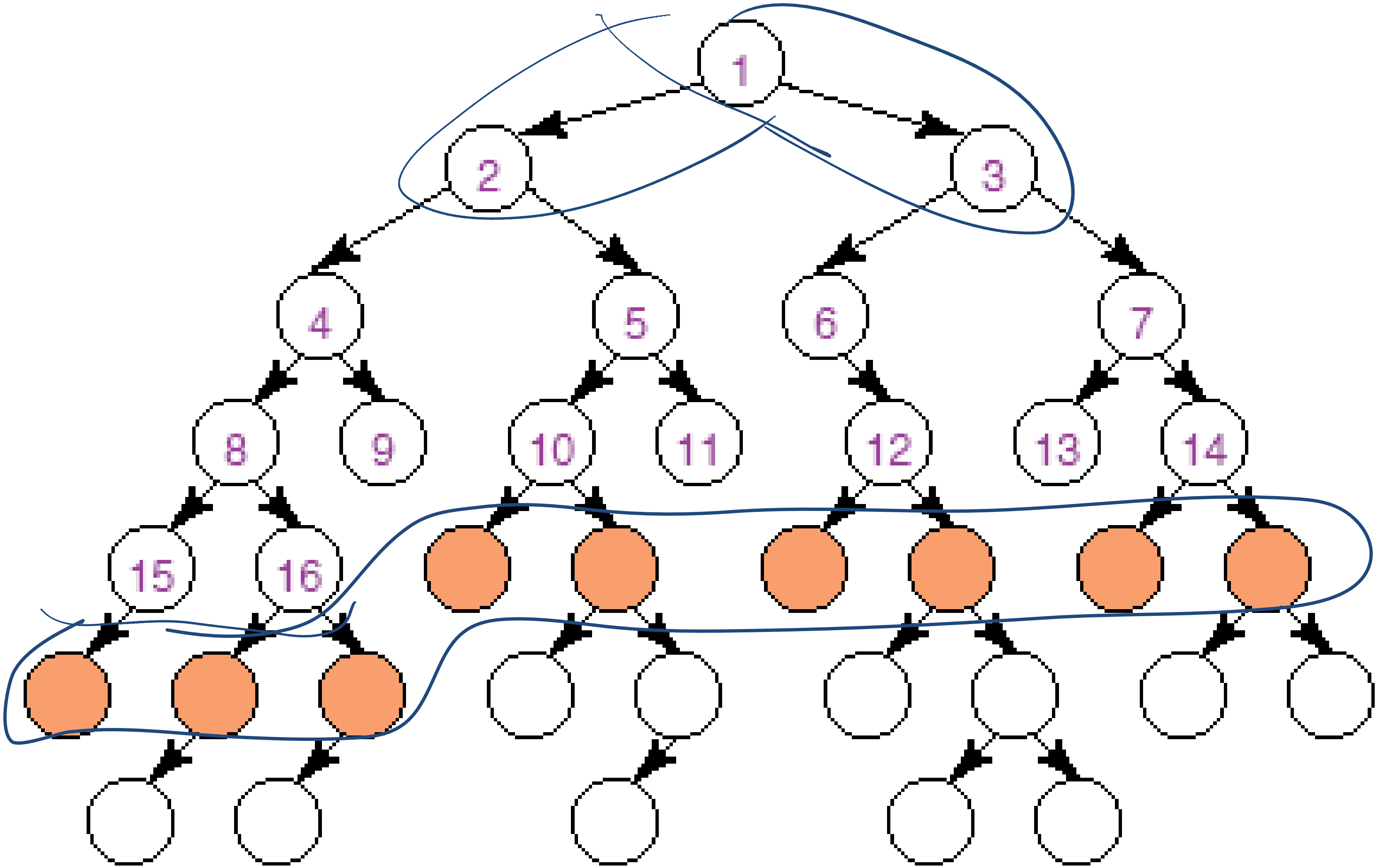
Breadth-first Search: BFS

- Breadth-first search treats the frontier as a **queue**
  - it always selects one of the earliest elements added to the frontier.

Example:

  - the frontier is $[p_1, p_2, \ldots, p_r]$
  - neighbors of the last node of p_1 are $\{n_1, \ldots, n_k\}$
- What happens?
  - p_1 is selected, and its end tested for being a path to the goal.
  - New paths are created attaching $\{n_1, \ldots, n_k\}$ to p_1
  - These follow p_r at the end of the frontier.
  - Thus, the frontier is now $[p_2, \ldots, p_r, (p_1, n_1), \ldots, (p_1, n_k)]$.
  - p_2 is selected next.

Illustrative Graph - Breadth-first Search



Analysis of Breadth-First Search

- Is BFS complete?
  - Yes
  - In fact, BFS is guaranteed to find the path that involves the fewest arcs (why?)
- What is the time complexity, if the maximum path length is *m* and the maximum branching factor is *b*?
  - The time complexity is ? $O(b^m)$? must examine every node in the tree.
  - The order in which we examine nodes (BFS or DFS) makes no difference to the worst case: search is unconstrained by the goal.
- What is the space complexity?
  - Space complexity is ? $O(b^m)$?

Using Breadth-first Search

- When is BFS appropriate?
  - space is not a problem
  - it's necessary to find the solution with the fewest arcs
  - although all solutions may not be shallow, at least some are

optimality

- When is BFS inappropriate?
  - space is limited
  - all solutions tend to be located deep in the tree
  - the branching factor is very large

What have we done so far?

GOAL: study search**, a set of basic methods underlying many intelligent agents**

AI agents can be very complex and sophisticated

Let's start from a very simple one, **the deterministic, goal-driven agent** for which: he sequence of actions and their appropriate ordering is the solution

We have looked at two search strategies DFS and BFS:

- To understand key properties of a search strategy
- They represent the basis for more sophisticated (heuristic / intelligent) search

Learning Goals for today's class

- Apply basic properties of search algorithms: completeness, optimality, time and space complexity of search algorithms.

	comp	opt	time	space
DFS	False	False	b^m	mb
BFS	True	True	b^m	b^m

- Select the most appropriate search algorithms for specific problems.
  - BFS vs DFS vs IDS vs BidirS-
  - LCFS vs. BFS –
  - A* vs. B&B vs IDA* vs MBA*

next 4 lectures

informed

Next Class

- Search with cost
- Start Heuristic Search

(textbook.: start 3.6)

Heuristics Depth-first Search

- What is still left unspecified by DFS?

- ordering