COMP 472: Artificial Intelligence
State Space Search part #3
State Space Representation video #1

- Russell & Norvig – Sections 3.1-3.3

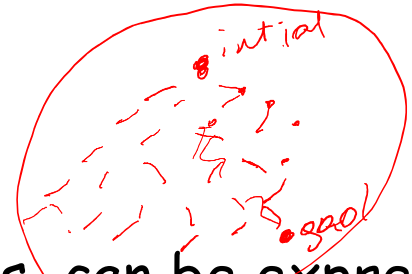
Today

1. State Space Representation

video #1

2. State Space Search
   a) Overview
   b) Uninformed search
      1. Breadth-first and Depth-first
      2. Depth-limited Search
      3. Iterative Deepening
      4. Uniform Cost
   c) Informed search
      1. Intro to Heuristics
      2. Hill climbing
      3. Greedy Best-First Search
      4. Algorithms A & A*
      5. More on Heuristics
   d) Summary

Motivation



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- Many AI problems, can be expressed in terms of going from an initial state to a goal state
  - *Ex: to solve a puzzle, to drive from home to Concordia…*

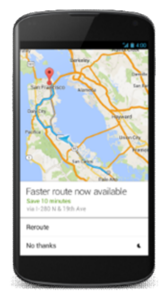
initial

goal

8-puzzle

15 moves

200 moves



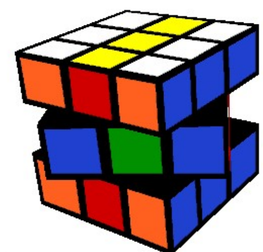
Google Maps

home

left right

straight right left

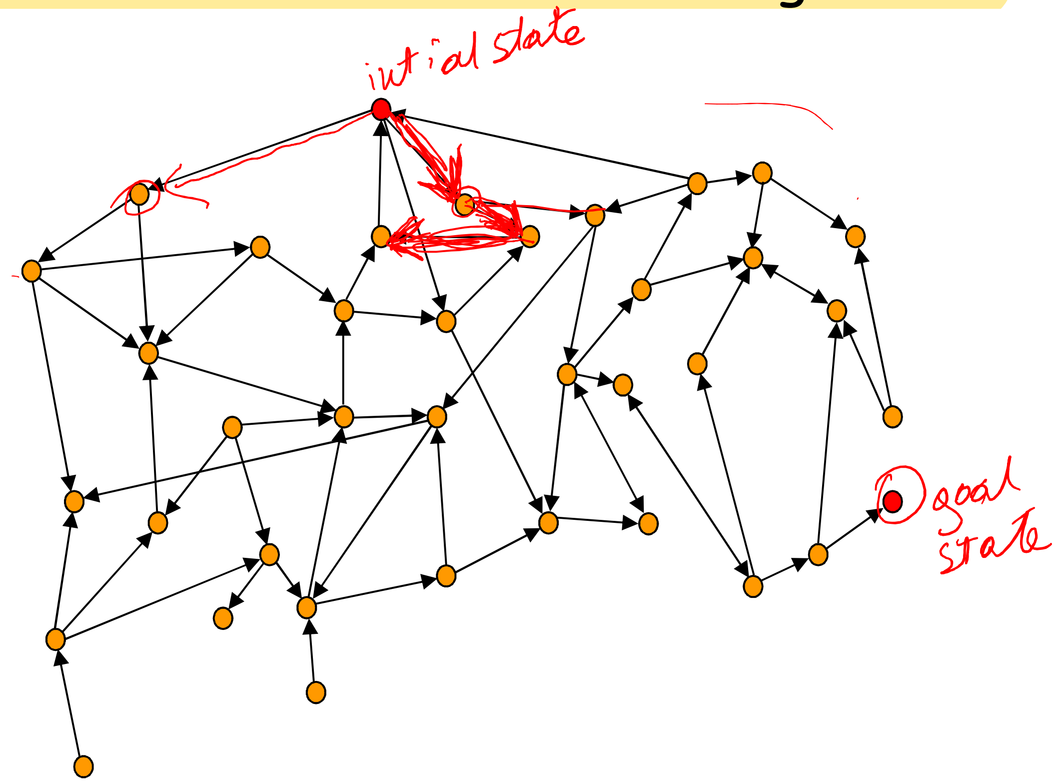
Concordia



Rubik's cube

Motivation

- Often, there is no direct way to find a solution to go from the initial state to a goal state
- but we can list the possibilities and search through them



Example: 8-Puzzle

State: Any arrangement of 8 numbered tiles and an empty tile on a 3x3 board

8	2	empty
3	4	7
5	1	6

Initial state

1	2	3
4	5	6
7	8	

Goal state

there are several standard goals states for the 8-puzzle

1	2	3
4	5	6
7	8	

1	2	3
8		4
7	6	5

...

(n^2-1)-puzzle

8	2	
3	4	7
5	1	6

8-puzzle

4

4

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	

15-puzzle

....

15-Puzzle

Invented in 1874 by Noyes Palmer Chapman …

but Sam Loyd claimed he invented it!

Sam Loyd

see Sam Loyd's book of puzzles:
https://archive.org/stream/CyclopediaOfPuzzlesLoyd/Cyclopedia_of_Puzzles_Loyd#mode/2up

https://en.wikipedia.org/wiki/Sam_Loyd

State Space

- Problem is represented by:
  1. Initial State
     - starting state
     - ex. unsolved puzzle, being at home
  2. Set of operators / moves / actions
     - actions responsible for transition between states
  3. Goal test function
     - Applied to a state to determine if it is a goal state
     - ex. solved puzzle, being at Concordia
  4. Path cost function
     - Assigns a cost to a path to tell if a path is preferable to another

	cost	cost
up	1	3
down	1	1
left	1	2
right	1	4
	least nb of moves	lowest cost

goal(...) → T

→ F

goal(...) = T

- State space:
  - the set of all states that can be reached from the initial state by any sequence of action

initial

comp 352

- Search algorithm:
  - how the search space is visited

Example: The 8-puzzle

goal

8	2	
3	4	7
5	1	6

= false

1- Initial state

goal

1	2	3
4	5	6
7	8	

= True

Goal state

2- Set of operators:
  blank moves up, blank moves down, blank moves left, blank moves right

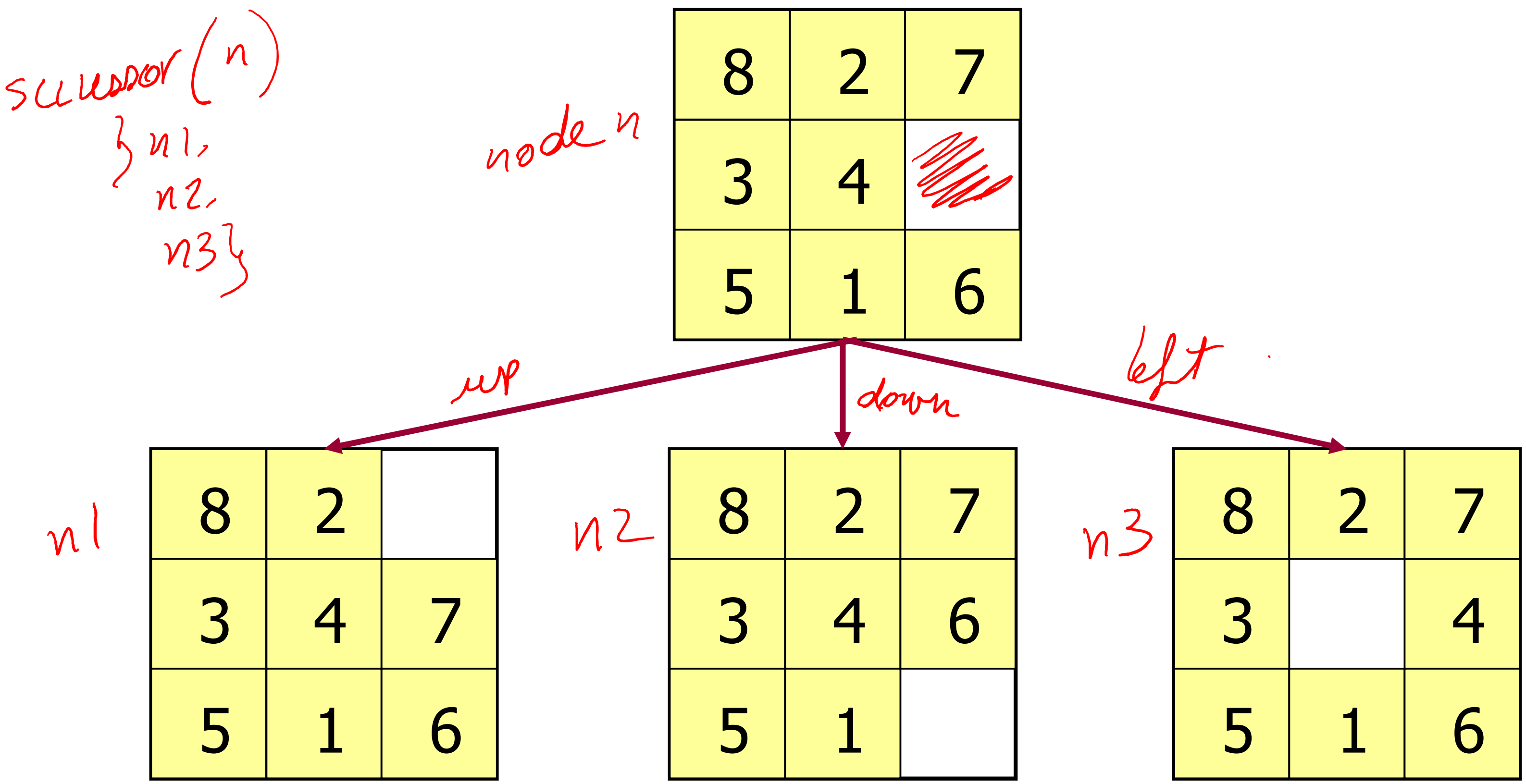
3- Goal test function:
  state matches the goal state

4- Path cost function:
  each movement costs 1
  so the path cost is the length of the path (the number of moves)

source: G. Luger (2005)

8-Puzzle: Successor Function

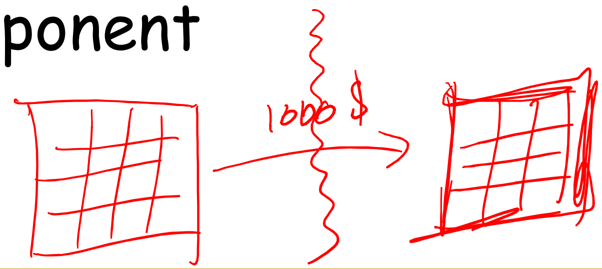
{children

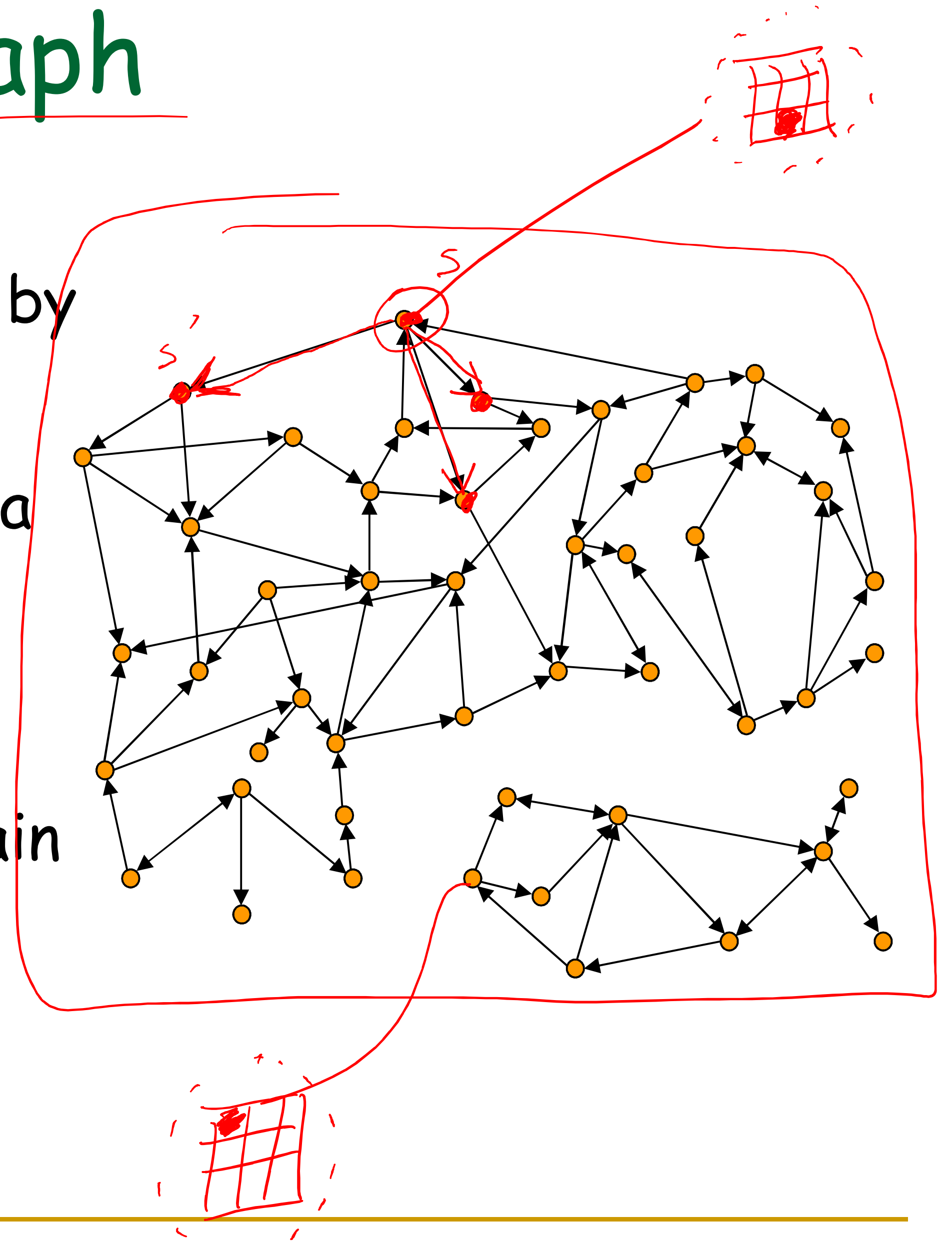


Search is about the exploration of alternatives

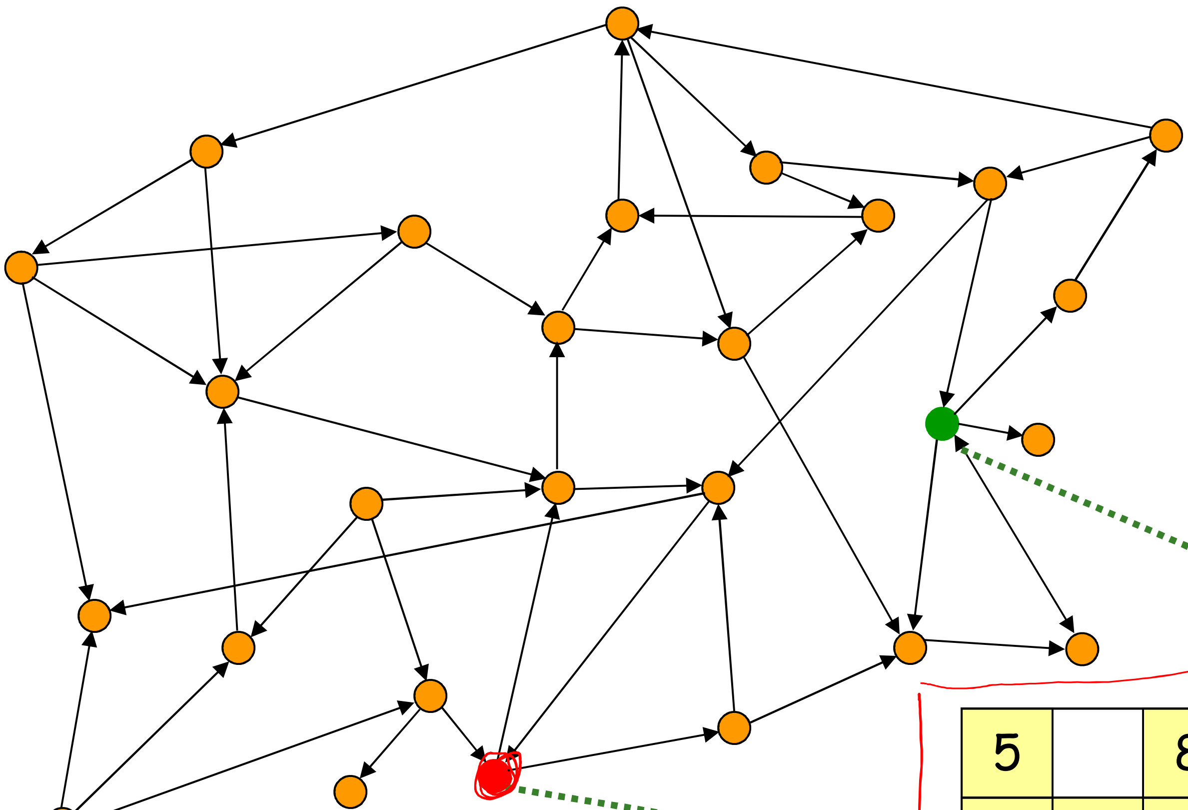
State Space Graph

- Each state is represented by a distinct node
- An arc (or edge) connects a node s
  to a node s' if
  s' ∈ SUCCESSOR(s)
- The state graph may contain more than one connected component





Just to make sure we're clear…



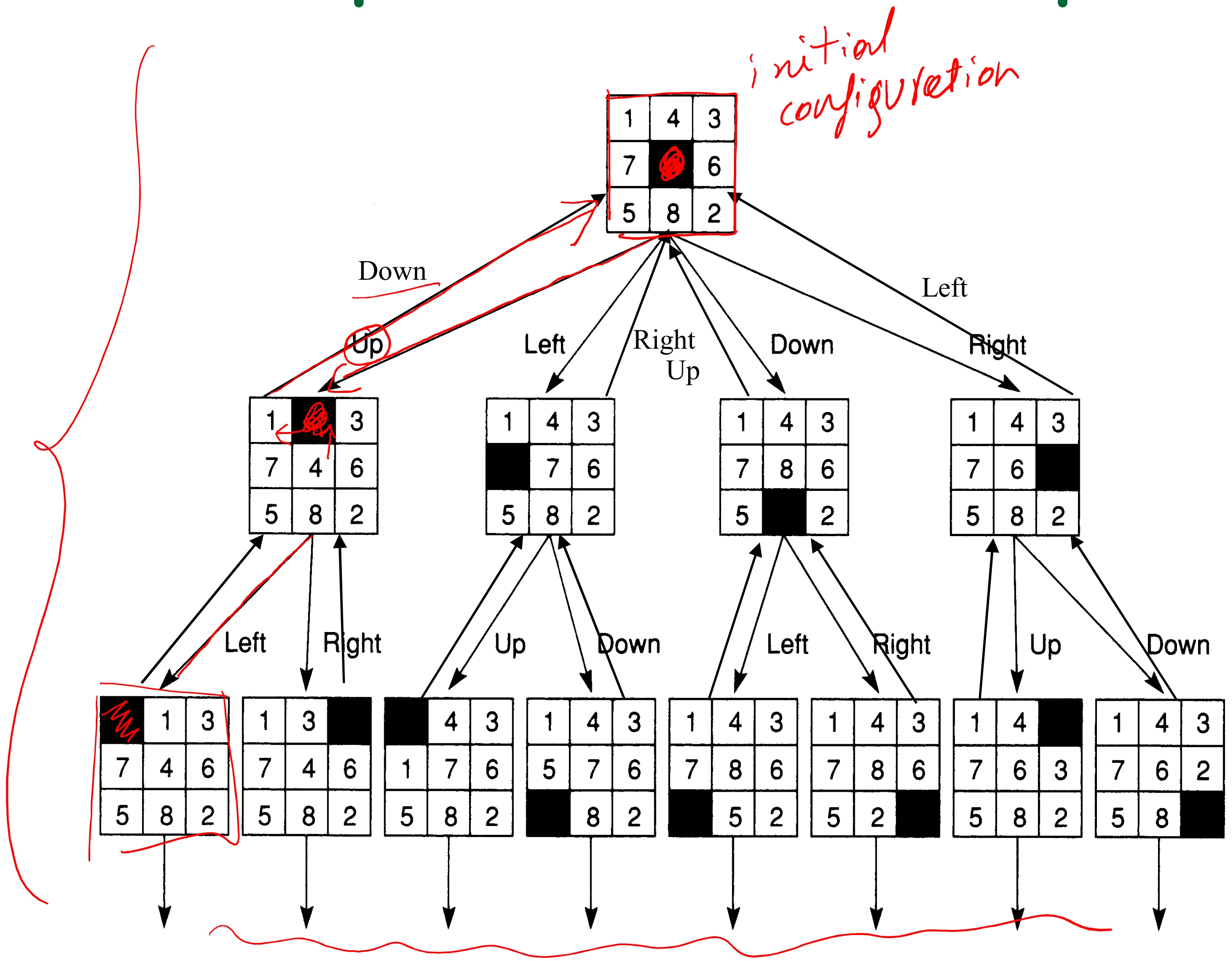
5		8
4	2	1
7	3	6

Initial state

1	2	3
4	5	6
7	8	

Goal state

State Space for the 8-puzzle



source: G. Luger (2005)

Size of state spaces

- For the (n-1)-puzzle:
  - Nb of states:
    - 8-puzzle --> 9! = 362,880 states
    - 15-puzzle --> 16! ~ 2.09 x 10^{13} states
    - 24-puzzle --> 25! ~ 10^{25} states
  - At 100 millions states/sec:
    - 8-puzzle --> 0.036 sec
    - 15-puzzle --> ~ 55 hours
    - 24-puzzle --> > 10^9 years

5

5

goal(state) → T
→ F

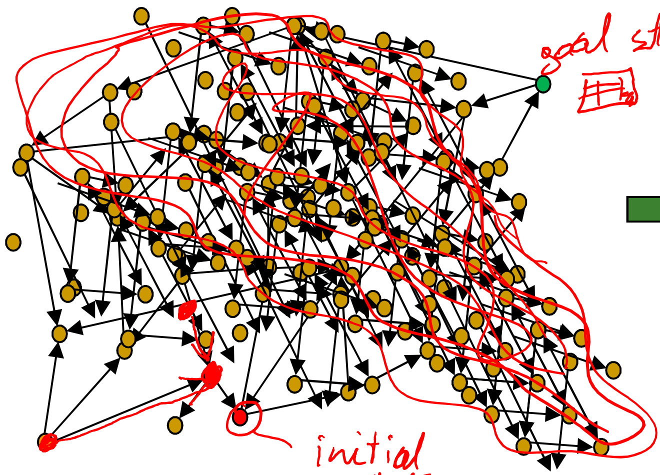
- For real problems:
  - state spaces are way too large to be generated in advance and searched after
  - so it is generated dynamically <u>while</u> searching.

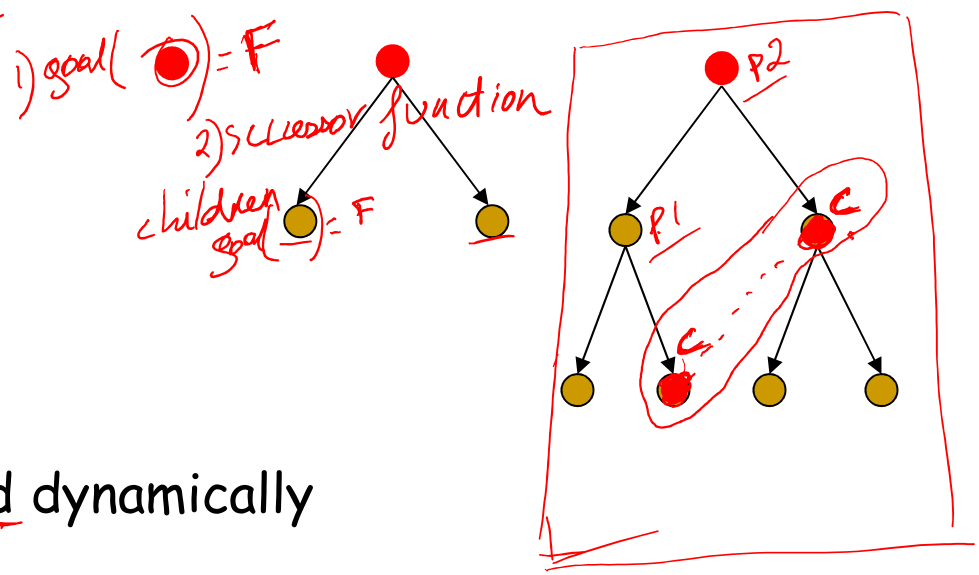
goal(•) → T
→ F

successor

s(•)

State Space Graph as a Search Tree



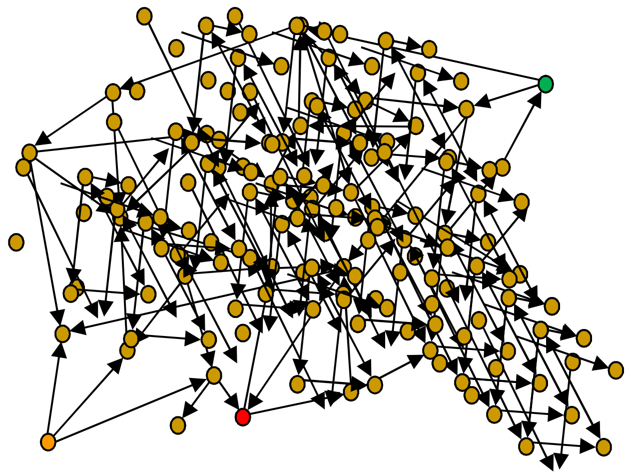


Search tree

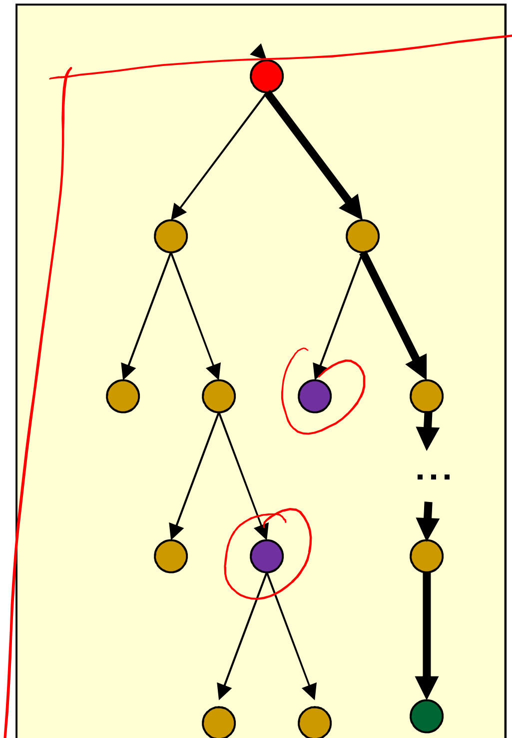
- The state space is generated dynamically while searching.
  - we explore a node:
    - if it the goal, stop and trace back the path from the initial node
    - if it is not the goal, then generating its successors/children and explore these recursively
  - to avoid cycles, the search algorithm will check for duplicate nodes.

solution path

State Space Graph as a Search Tree



Theoretical State Space Graph



Dynamically created
Search tree

So now, we just need an efficient search algorithm

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Up Next

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