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

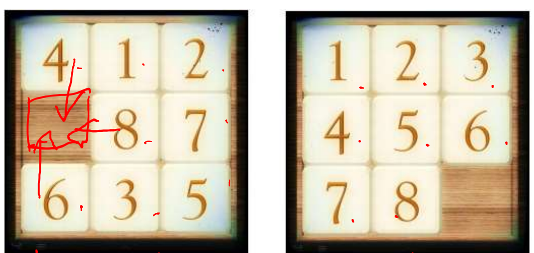
initial

goal

1970

我们不知道具体怎样从initial state变成goal state，但我们可以通过一些action，从一个state到另一个state，把这些possible state列出来，搜索goal state

- 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…*



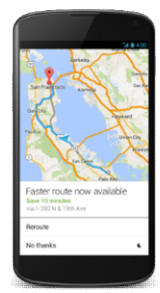
initial goal

8-puzzle

15 moves

200 moves

15move
200move不一定



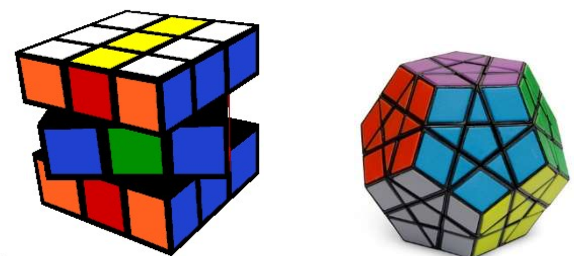
Google Maps

home

left right

street right left

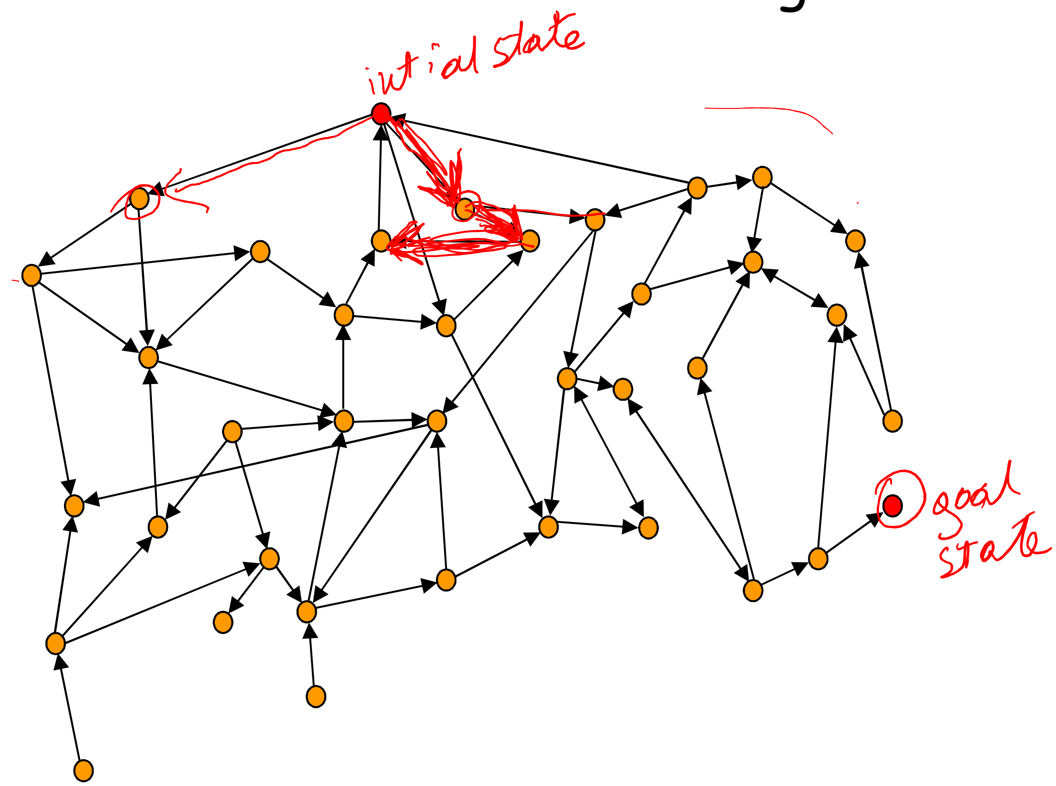
Concordia



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

...

$(n^2\text{-}1)$-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

如果我们能用这四步描述问题，那么就能使用state space search

- State space:
  - the set of all states that can be reached from the initial state by any sequence of action
- Search algorithm:
  - how the search space is visited

最后我们需要一个search algorithm

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

有的时候求最低cost

有的时候求最小move数量(COST一样)

goal(···) → T / F

goal(···) = T

initial

goal

comp 352

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

格子例如7往上移，相当于空格往下移，我们移动空格

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)

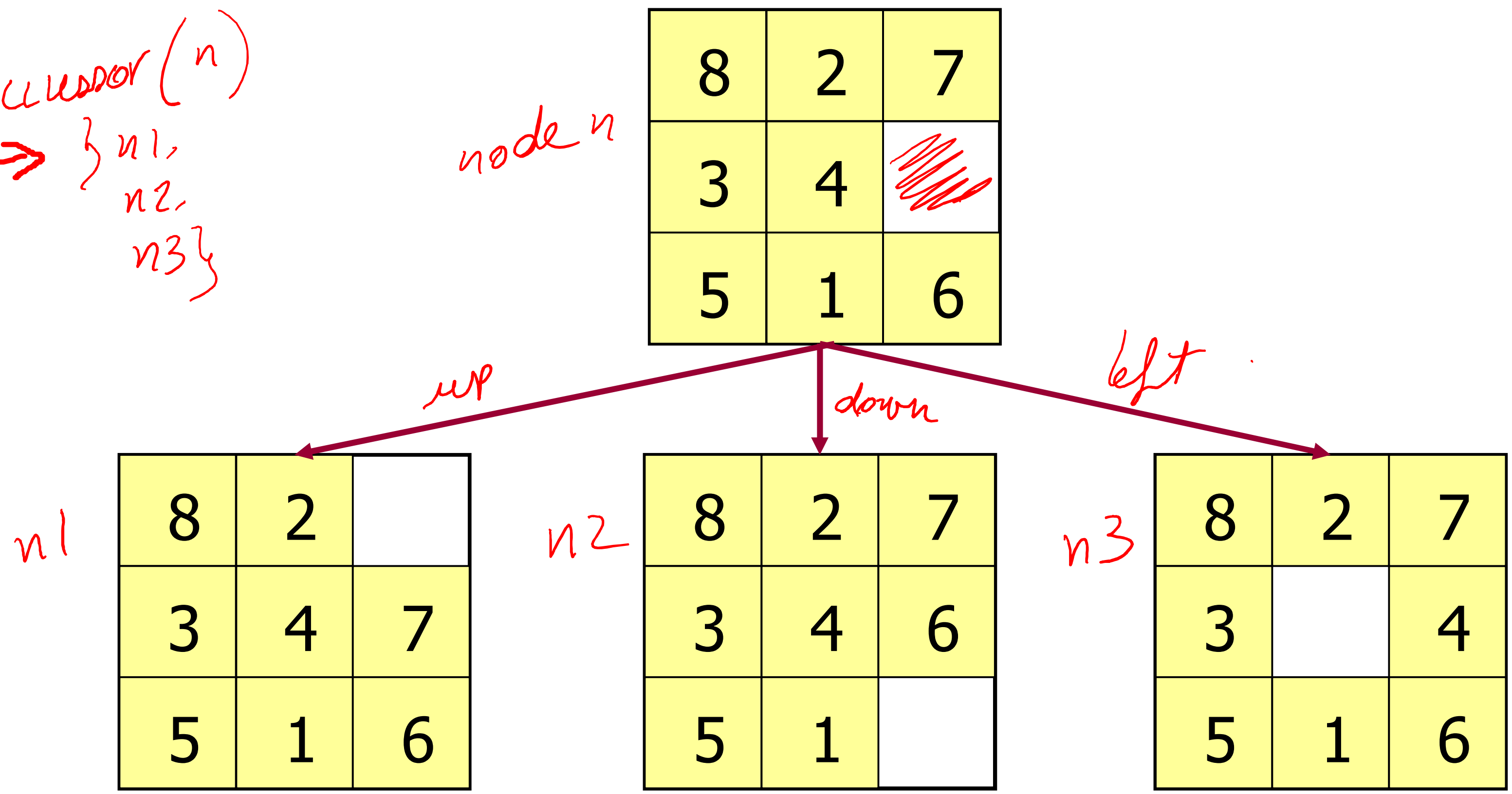
source: G. Luger (2005)

8-Puzzle: Successor Function 后继函数

{children

successor(n)生成了n1,n2,n3

successor(n)
→ {n1,
n2,
n3}



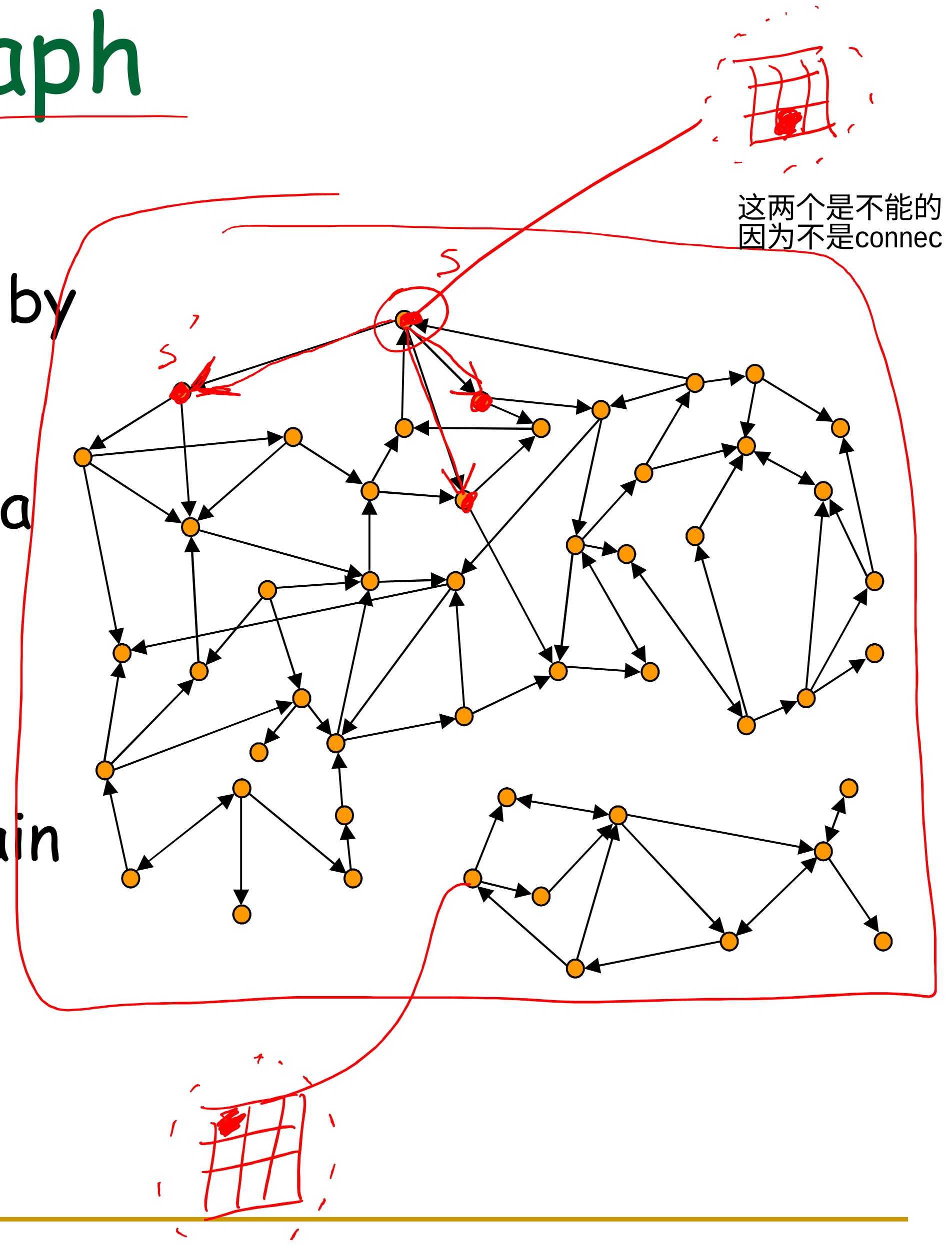
Search is about the exploration of alternatives

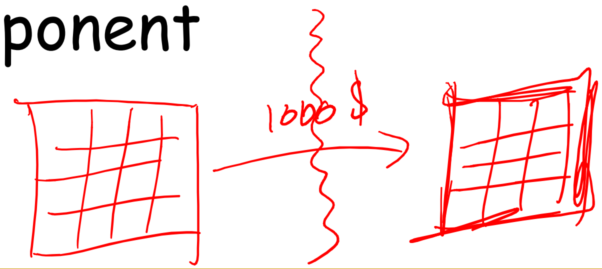
State Space Graph

对每个node使用successor function
如果结果是其中一个点，相连

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

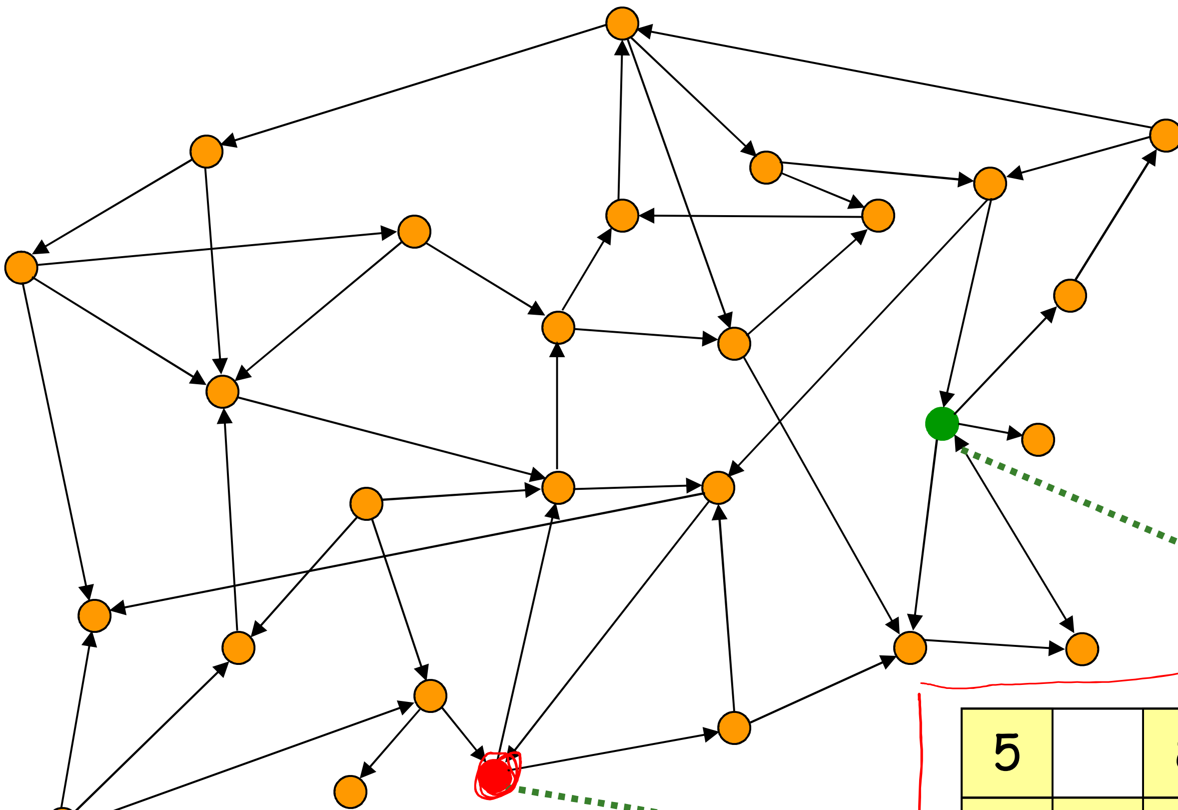
这两个是不能的，
因为不是connected的





1000块钱悬赏解Puzzle但实际上是不可能的因为不是connected

Just to make sure we're clear…



每个Node代表了一种状态

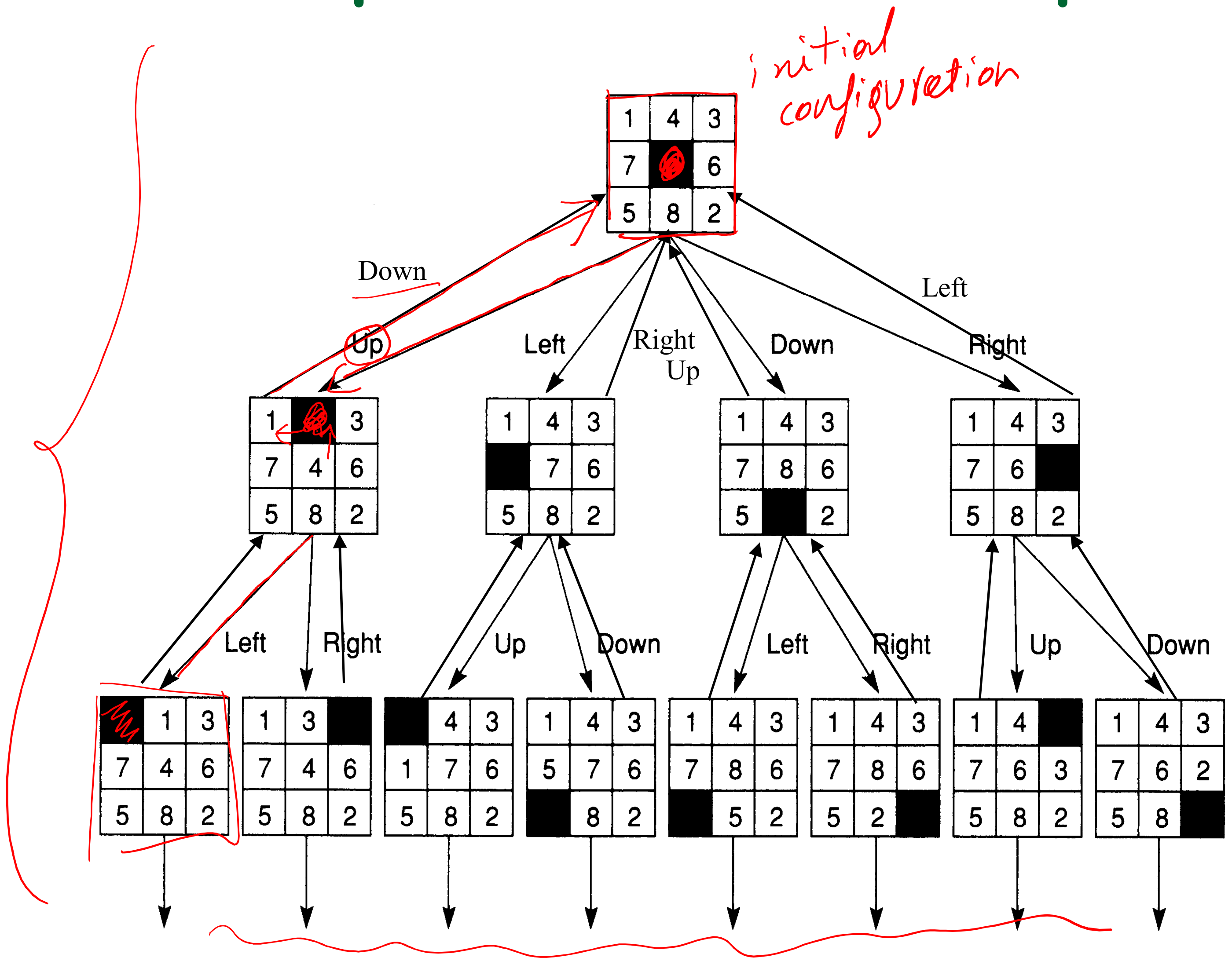
5		8
4	2	1
7	3	6

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! ~ 2.09×10^{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

无非就是while里加了一步goal，如果得到了，backtrack，得到路径，不行，进行下一个动作

goal(state) → T
→ F

- For real problems:
  - state spaces are way too large to be generated in advance and searched after state space经常容易太大了，很难先生成，再搜索
  - so it is generated dynamically while searching.

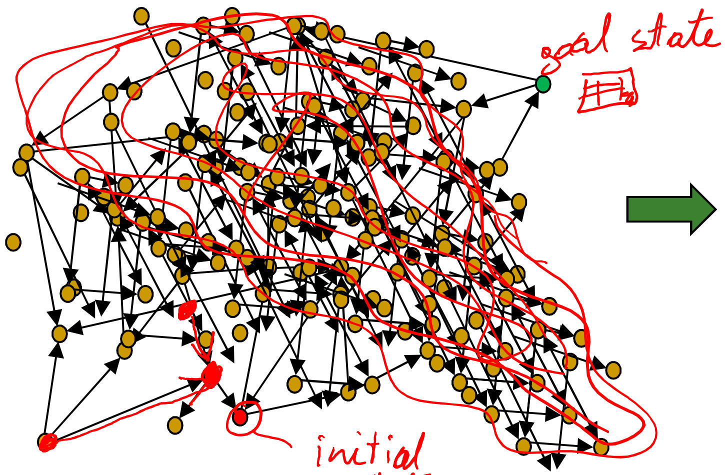
goal(·) → T
→ F

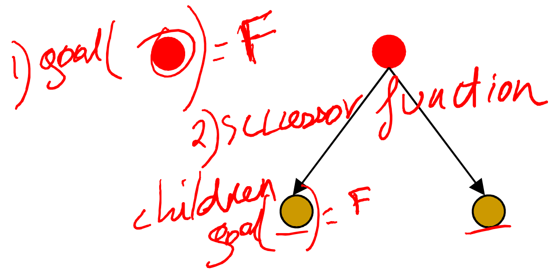
successor

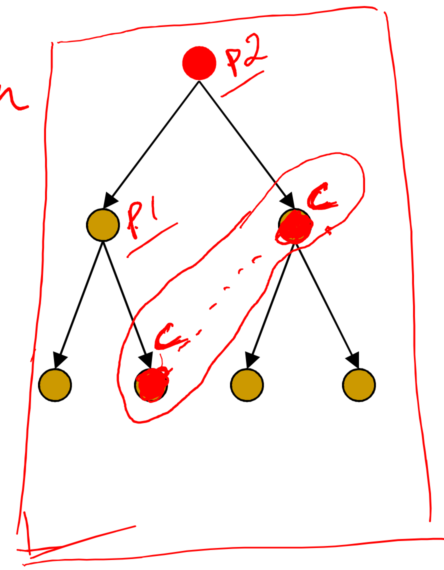
通常动态生成，动态搜索

State Space Graph as a Search Tree

实际上我们在生成一个search tree







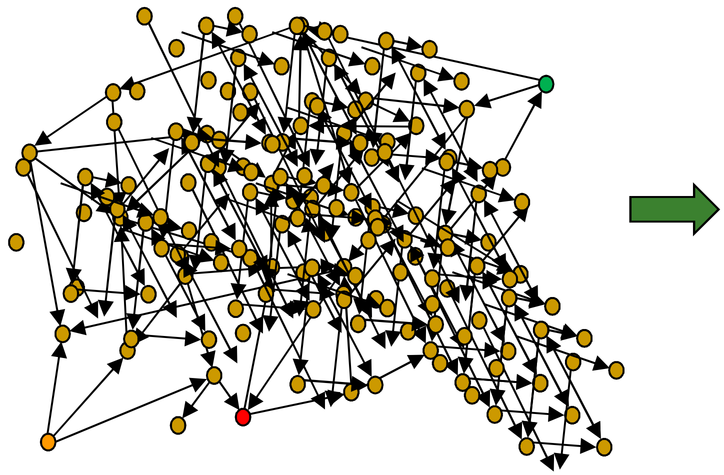
有可能两个点是同一个C，只是有两个不同的parent

- 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 / solution path
    - 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.

为了避免循环我们要避免右上角两个C的情况

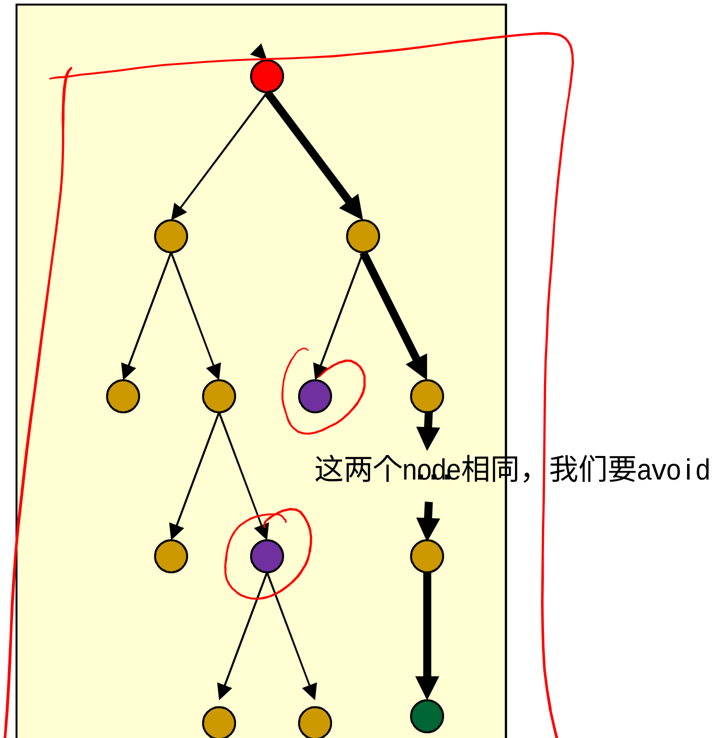
Search tree

State Space Graph as a Search Tree



Theoretical State Space Graph

So now, we just need an efficient search algorithm



Dynamically created Search tree

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video #2

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novelty