Introduction to Artificial Intelligence

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Department of computer science
Higher School of mathematics and computer science
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Basic information about course

- 1H30 Tutorial 1H30 Practical lab
- Text: Artificial Intelligence: A Modern Approach, Fourth edition, 2020, by Stuart Russell and Peter Norvig
- Prerequisites:
  - programming C (or C++) or Java or python or R
  - Algorithmis and data structures
  - Discrete mathematics and probability
- Grading:
  - Midterm exams, Final exam, Participation, practical Work

Basic information about course

ECUEF441 : Fondements & Programmation IA

- Objectifs: Permettre aux étudiants de maitriser les fondements de l’intelligence artificielle
- Partie 1: Fondement de l'IA

1. Introduction
2. Résolution d’un problème par recherche
   1. Formulation d’un problème
   2. largeur d’abord, profondeur d’abord, profondeur limitée, profondeur limitée itérative, recherche best-first, hill climbing, algorithme A*, heuristiques, recherche en faisceau (beam search), recherche par recuit-simulé,
   3. Satisfaction de contraintes et recherche (CSP),
   4. Jeux stratégiques et recherche : min-max et alpha-beta
   3. Systèmes experts: Base de connaissances : bases de faits, base de règles, Inférence : chaînage avant, arrière et mixte

Introduction to Artificial Intelligence

- https://www.facebook.com/enovarobotics/videos/520389588622003/
- https://www.youtube.com/watch?v=LSHZ_b05W7o

Artificial : not natural (car, computer, pen, television etc)

Intelligence: think, learn, understand

Artificial intelligence →Think , behave like a human

Robot, agent artificiel, intelligent program

Research, experimentation, simulation, test

What is AI?

- https://www.youtube.com/watch?v=UFDOY1wOOz0
- A field that focuses on developing techniques to enable computer systems to perform activities that are considered intelligent (in humans and other animals)." [Dyer]
- "The science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable." [McCarthy]

What is AI?

- " "The design and study of computer programs that behave intelligently." [Dean, Allen, & Aloimonos]
- "AI, broadly defined, is concerned with intelligent behavior in artifacts. Intelligent behavior, in turn, involves perception, reasoning, learning, communicating, and acting in complex environments." [Nilsson]
- "The study of [rational] agents that exist in an environment and perceive and act." [Russell & Norvig]

What is AI?

"[The automation of] activities that we associate with human thinking…" *Bellman, 1978* Thinking like a human	"The study of mental faculties through the use of computational models" *Charniak & McDermott, 1985* Thinking rationally
"The art of creating machines that perform functions that require intelligence when performed by people." *Kurzweil, 1990* Acting like a human	"The branch of computer science that is concerned with the automation of intelligent behavior." *Luger, 2002* Acting rationally

"Chinese room" argument [Searle 1980]

- Person who knows English but not Chinese sits in room
- Receives notes in Chinese
- Has systematic English rule book for how to write new Chinese characters based on input Chinese characters, returns his notes

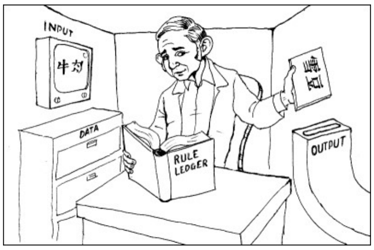


image from http://www.unc.edu/~prinz/pictures/c-room.gif

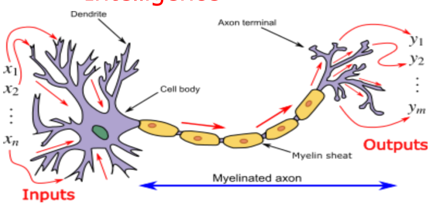
Person=CPU, **rule book**=AI program, really also need lots of paper (storage)
Has no understanding of what they mean
But from the outside, the room gives perfectly reasonable answers in Chinese!

Searle's argument: the room has no intelligence in it!

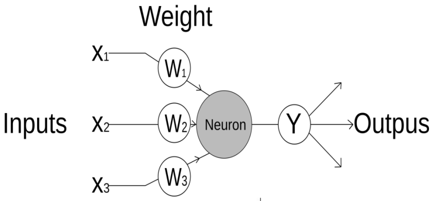
We Talked To Sophia: https://www.youtube.com/watch?v=78-1MlkxyqI

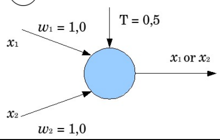
A Brief History of AI

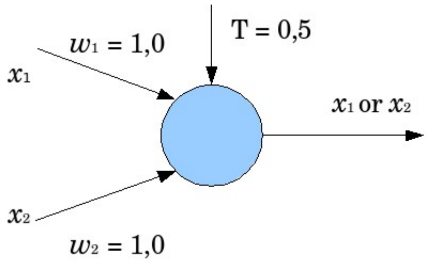
- 1943: McCulloch and Pitts propose a model of artificial neurons
- 1956 Minsky and Edmonds build first neural network computer, the SNARC
- The Dartmouth Conference (1956):
  - John McCarthy organizes a two-month workshop for researchers interested in neural networks and the study of intelligence
  - Agreement to adopt a new name for this field of study: Artificial Intelligence



https://nischal.info.np/very-stupid-introduction-to-deep-learning.html





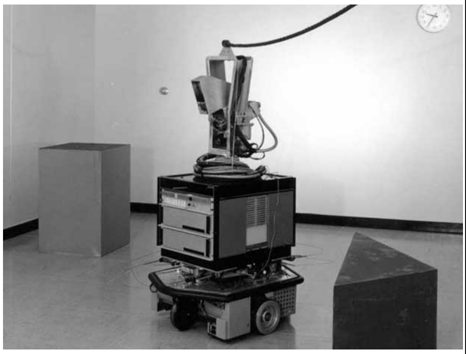


Y=x1*w1+x2*w2+T
Z=f(y) : si y>0.5 alors 1 si non 0
00 →0
01 →1
10 →1
11→1

A Brief History of AI

- 1952-1969 Enthusiasm:
  - Lots of work on neural networks

Arthur Samuel's checkers player (1959). Machine Learning: Field of study that gives computers the ability to learn without being explicitly programmed.



https://www.sri.com/case-studies/the-man-the-myth-the-legend-meet-shakey-the-robot-the-worlds-first-ai-based-robot/
Naissance de la robotique

A Brief History of AI

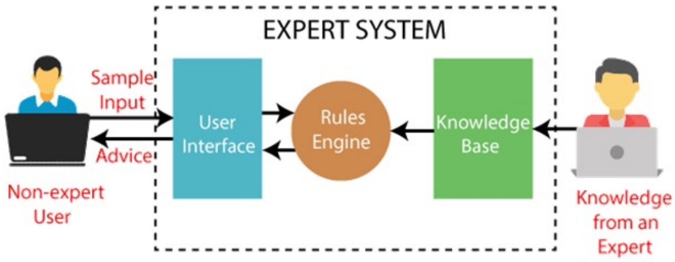
- 1966-1974 Reality:
  - AI problems appear to be too big and complex
  - Computers are very slow, very expensive, and have very little memory (compared to today)

Year of Release	Processor	No. of Transistors	Clock Speed
1971	Intel 4004	2300	740 KHz
1972	Intel 8008	6000	800 KHz
1978	Intel 8086	29000	5 MHz
1993	Intel Pentium	3.1 million	50 MHz
2000	Intel Pentium 4	42 million	1.5 GHz
2017	AMD Ryzen	4.2 billion	4.4 GHz

https://www.zzoomit.com/evolution-of-computer-processors/

A Brief History of AI

- **1969-1979 Knowledge-based systems:**
  - Birth of expert systems
  - Idea is to give AI systems lots of information to start with
- **1980-1988 AI in industry:**
  - R1 becomes first successful commercial expert system
  - Some interesting phone company systems for diagnosing failures of telephone service



https://www.maixuanviet.com/what-is-an-expert-system.vietmx

A Brief History of AI

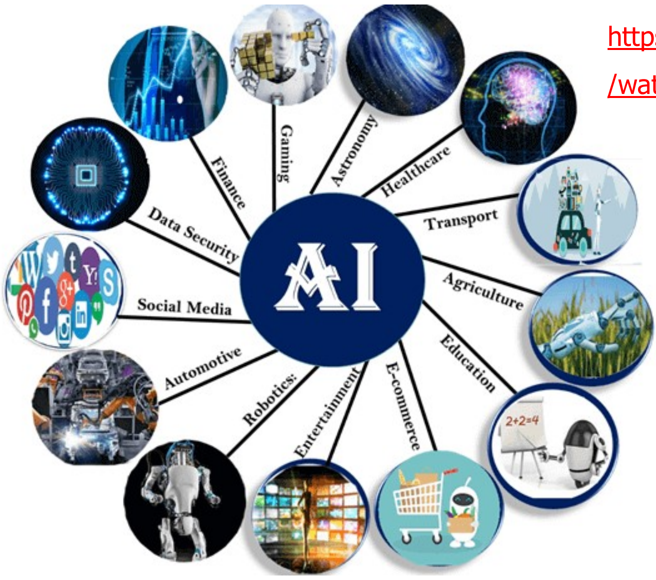
- **1990s to the present:**
  - 2/96: Kasparov vs Deep Blue
    - Kasparov victorious: 3 wins, 2 draws, 1 loss
  - 3/97: Kasparov vs Deeper Blue
    - First match won against world champion
    - 512 processors: 200 million chess positions per second

Deep Blue
Deep Learning
Neural Networks

Google's Go-playing AI still undefeated with victory over world number one...

Artificial Intelligence in 2016 - 2017

AI in practice



https://www.youtube.com/watch?v=AXgjEW2nA9I

https://www.javatpoint.com/application-of-ai

AI in practice

- **Robotics**
  - Mars rover: http://marsrovers.jpl.nasa.gov/home/index.html
  - Humanoid robots: http://www.ai.mit.edu/projects/humanoid-robotics-group/
  - Entertainment robots: http://www.us.aibo.com/
  - Vacuum cleaner robots: "Roomba"
- **Lanuage Systems**
  - Automatic translation: http://world.altavista.com/
  - You type, it types back: http://www.mrmind.com/mrmind3
- **Speech Systems**
  - Movie ticket reservations by phone: 1-800-Fandango
  - You talk, it types: IBM's ViaVoice

AI in practice

Modern variant: AOLiza [fragment from http://archives.cnn.com/2000/TECH/computing/08/29/aoliza.idg

five: just asking if richard can tell me about some good lobster diving spots thats it if this is a problem then forget iot i dont know whats going on here

AOLiza: that is interesting. please continue.

five: continue what just ask richard when he gets home about some lobster diving up hat way thats all if you got a problem with it then forget it,this isnt worht it i dont know whats been going on or what bev has told you but i havent done anything to anybody iam the one that got used and dumped

AOLiza: tell me more about that.

five: about what

AOLiza: what do you think?

five: therers nothing to tell she us3ed me then got tired of me said i wasnt her type anymore i was possesive and controlling

AOLiza: perhaps i already know you were possesive and controlling.

five: i was huh you nuts i gave her all the room she wanted never told nhewre what to do or where to go

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AI in practice

- **Vision Systems**
  - Face recognition and enhancement
    http://www.ri.cmu.edu/labs/lab_51.html
  - Automated driving - No Hands across America
  - Visual tracking systems
    http://www1.cs.columbia.edu/CAVE/research/demos/.index.html

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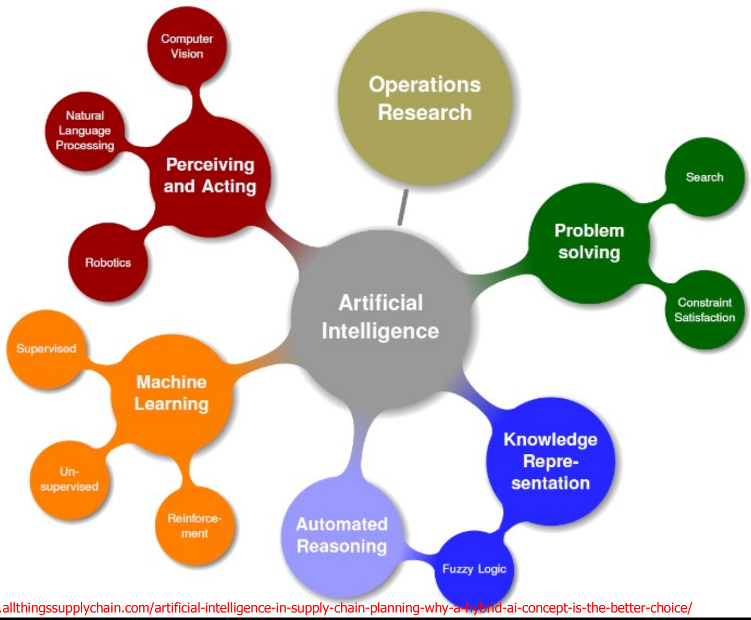
Some AI videos

- http://www.youtube.com/watch?v=ICgL1OWsn58&feature=related
- http://www.youtube.com/watch?v=HacG_FWWPOw&feature=related
- http://videolectures.net/aaai07_littman_ai/
- http://www.youtube.com/watch?v=ScXX2bndGJc
- https://www.youtube.com/watch?v=78-1MlkxyqI
- https://www.youtube.com/watch?v=xmt6OCBeS94
- https://www.youtube.com/watch?v=smM-Wdk2RLQ

Artificial intelligence



https://www.allthingssupplychain.com/artificial-intelligence-in-supply-chain-planning-why-a-hybrid-ai-concept-is-the-better-choice/

Search

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Search

- We have some actions that can change the state of the world
  - Change resulting from an action perfectly predictable
- Try to come up with a sequence of actions that will lead us to a goal state
  - May want to minimize number of actions
  - More generally, may want to minimize total cost of actions
- Do not need to execute actions in real life while searching for solution!
  - Everything perfectly predictable anyway

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A simple example: heating water

- Initial state : water 30°
- Goal state : water 70 °

Solution 1: Sequence of actions

Action 1: 1 mn T=80° →state water 45°=f(30°,80°,1mn)

Action 2: 1 mn 20 T=120° → sate water 75°=f(45°,120°,1.2 mn)

Action 3: 35 s T=50° →state water 68°

Action 4: 15° T=78° → state water 70°

→number of actions=4, resolution time=3 mn 10s

Solution 2: Sequence of actions

Action 1: 1.30 mn T=90° →state water 72°

Action 2: 25 s T=40° → sate water 70°

→number of actions=2, resolution time=1 mn 55s

Solution 3: Sequence of actions

Action 1: 5 mn T=85° →state water 70°

→number of actions=1, resolution time=5 mn

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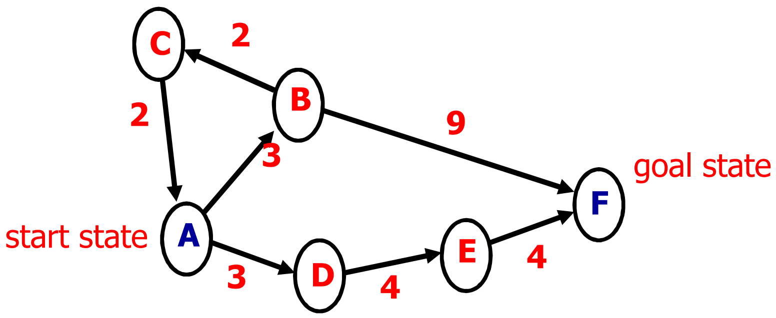
A simple example: traveling on a graph



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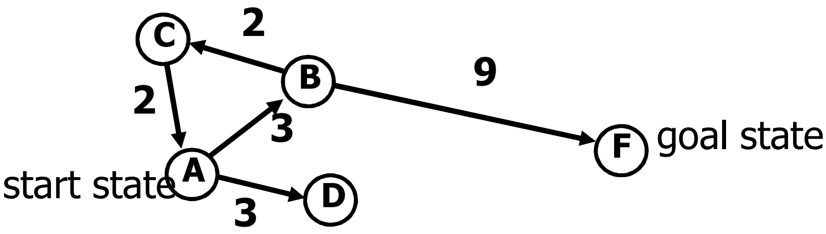
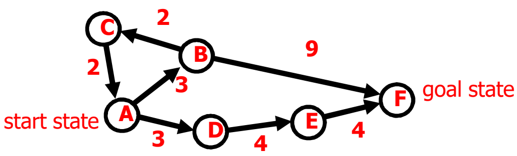
Searching for a solution



Solution A →B→F
2 actions
Cost =12



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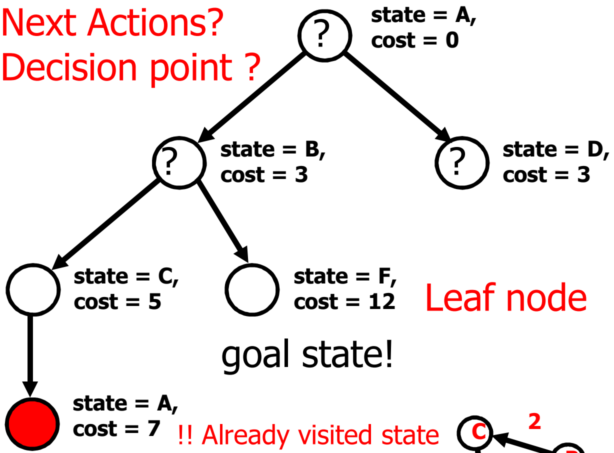
Search tree

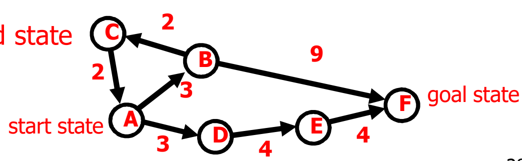
Internal node
Next Actions?
Decision point ?



Leaf node

goal state!

!! Already visited state



search tree nodes and states are not the same thing!

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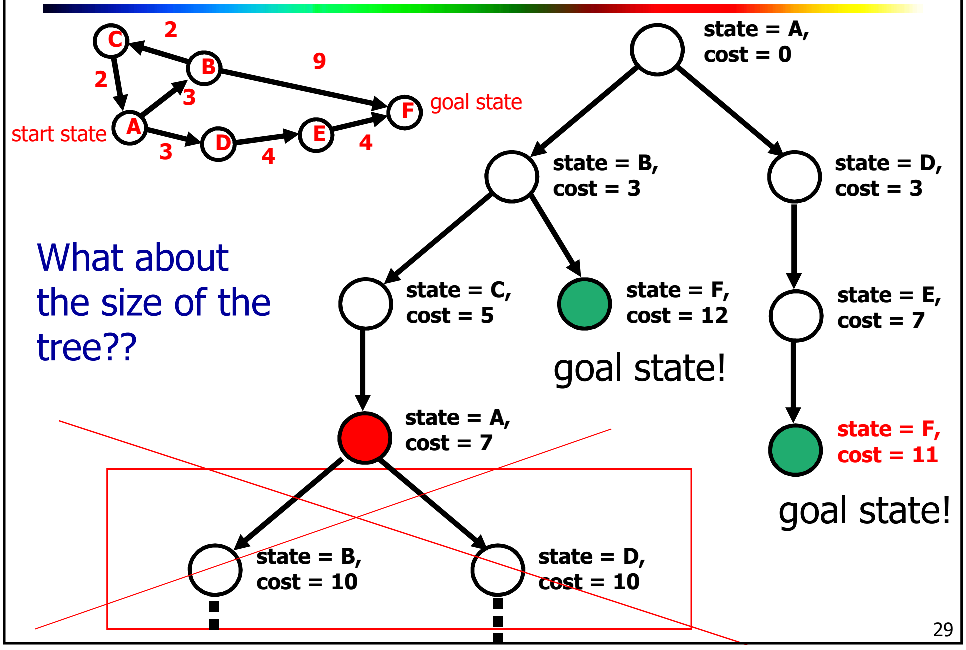
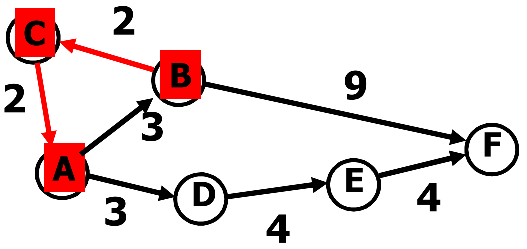
Full search tree



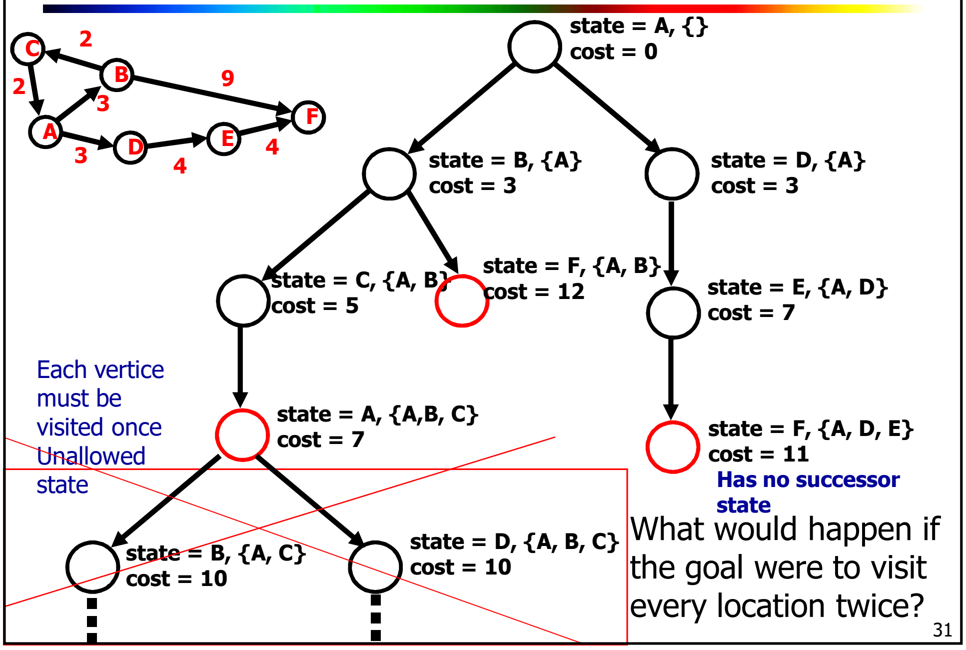
What about the size of the tree??

Changing the goal: want to visit all vertices on the graph



need a different definition of a state
"currently at A, also visited B, C already"
large number of states: $n*2^{n-1}$
could turn these into a graph, but…
Initial sate {} →possible actions
{A} or {B}or {C}or {D}or {E}or {F}

Full search tree



What would happen if the goal were to visit every location twice?

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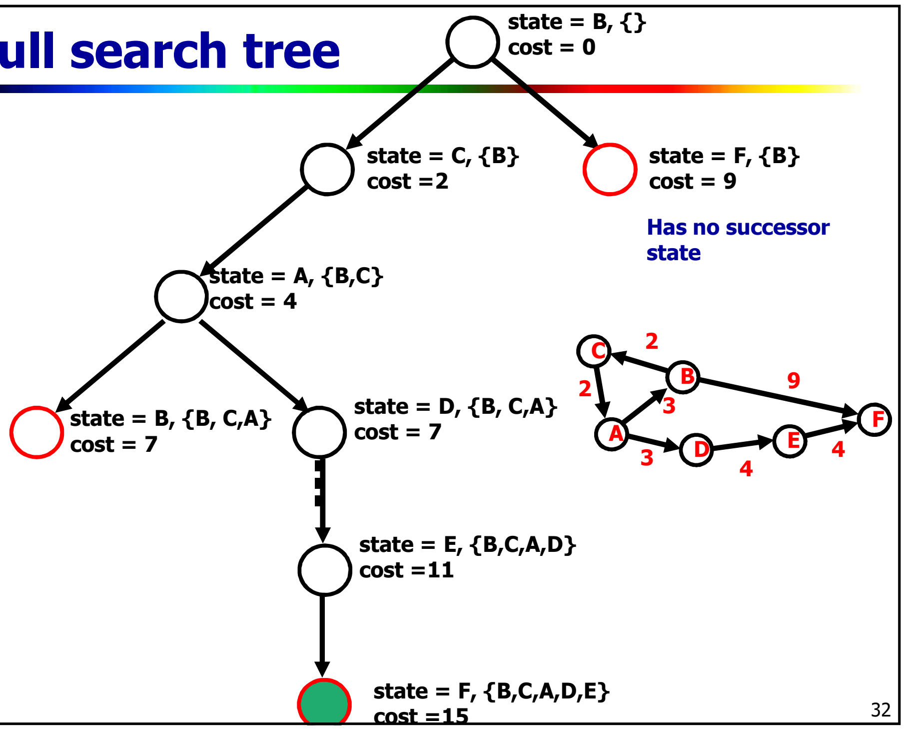
Full search tree



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Key concepts in search

- Set of states that we can be in
  - Including an initial state…
  - … and goal states (equivalently, a goal test)
- For every state, a set of actions that we can take
  - Each action results in a new state
  - Typically defined by successor function
    - Given a state, produces all states that can be reached from it
- Cost function that determines the cost of each action (or path = sequence of actions)
- Solution: path from initial state to a goal state
  - Optimal solution: solution with minimal cost

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8-puzzle

1		2
4	5	3
7	8	6

1	2	3
4	5	6
7	8	

goal state

fact(25)

15 511 210 043 330 985 984 000 000

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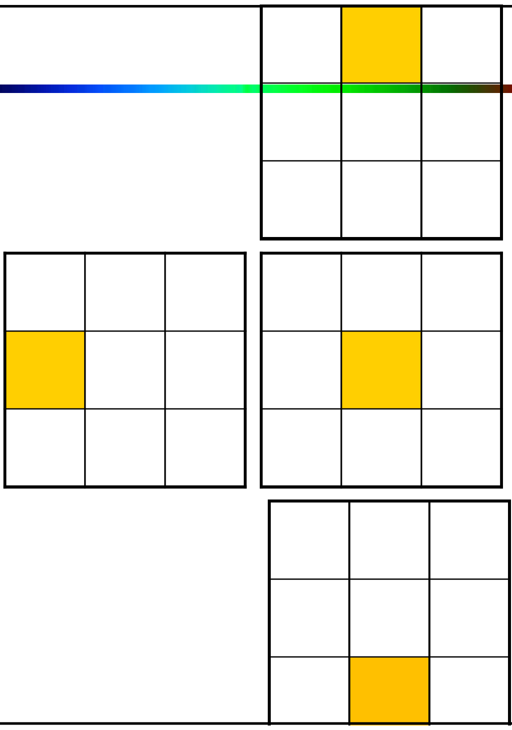
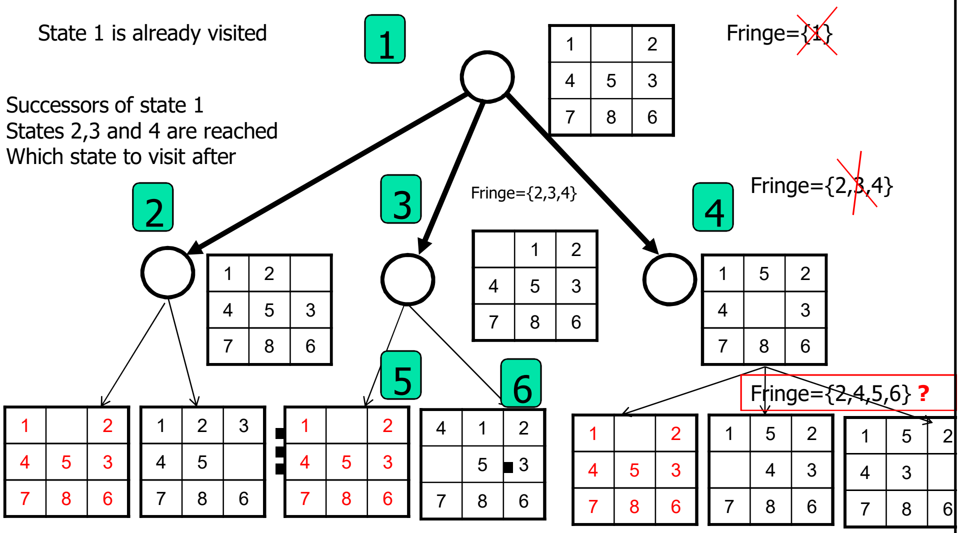


8-puzzle


State 1 is already visited
Successors of state 1
States 2,3 and 4 are reached
Which state to visit after
Fringe={1}
Fringe={2,3,4}
Fringe={2,3,4}
Fringe={2,4,5,6} ?
1
2
3
4
5
6

Generic search algorithm

- Fringe = set of nodes generated but not expanded
  = nodes we know we still have to explore
- *fringe := {node corresponding to initial state}*
- *loop:*
  - *if fringe empty, declare failure*
  - *choose and remove a node v from fringe*
  - *check if v's state s is a goal state; if so, declare success*
  - *if not, expand v, insert resulting nodes into fringe*
- Key question in search: *Which of the generated nodes do we expand next?*

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Uninformed search

- Uninformed search: given a state, we only know whether it is a goal state or not
- Cannot say one nongoal state looks better than another nongoal state
- Can only traverse state space blindly in hope of somehow hitting a goal state at some point
  - Also called blind search
  - Blind does **not** imply unsystematic!

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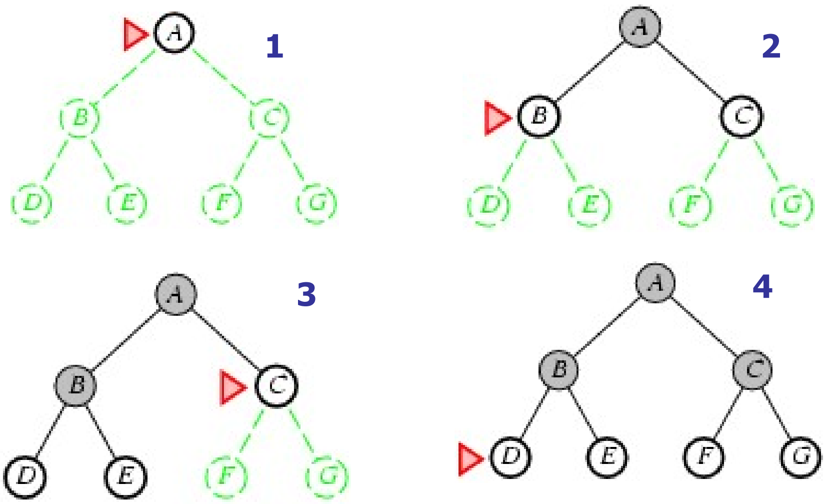
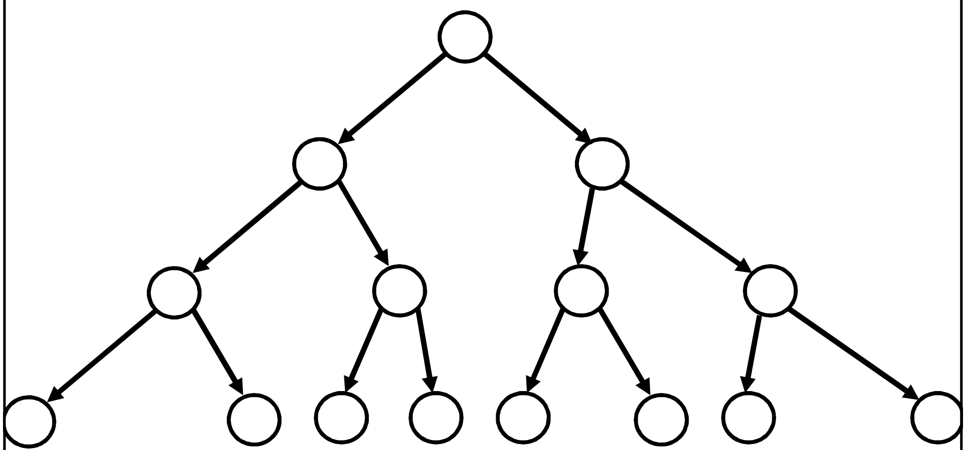
Blind search



Breadth-first search



Properties of breadth-first search

- Nodes are expanded in the same order in which they are generated
  - Fringe can be maintained as a First-In-First-Out (FIFO) queue
- BFS is complete: if a solution exists, one will be found
- BFS finds a shallowest solution
  - Not necessarily an optimal solution
- If every node has b successors (the branching factor), first solution is at depth d, then fringe size will be at least b^d at some point
  - This much space (and time) required ☹

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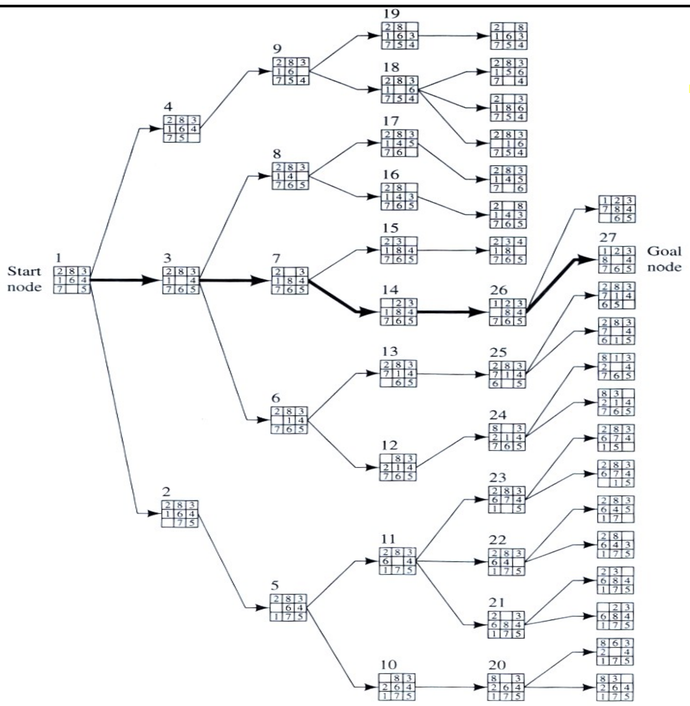
Example BFS



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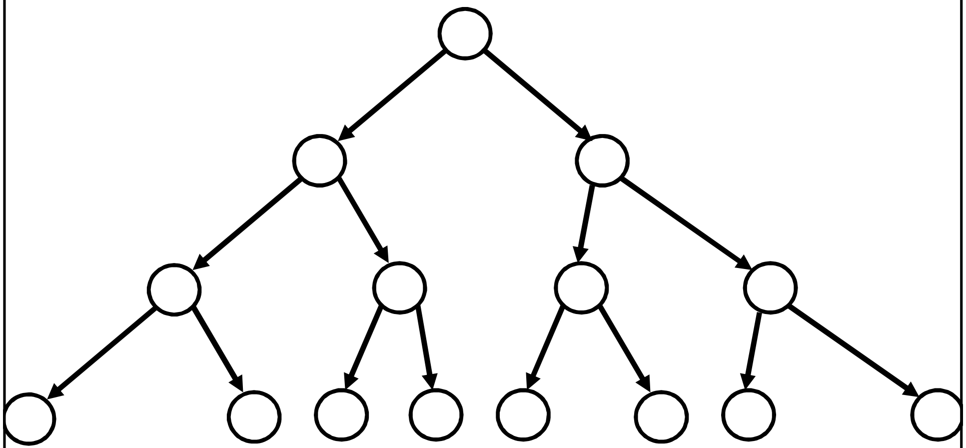
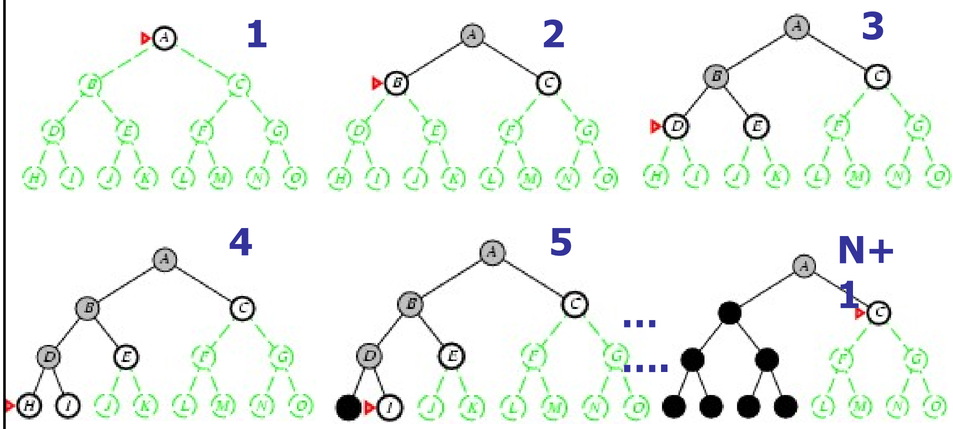
Depth-first search





Implementing depth-first search

- Fringe can be maintained as a Last-In-First-Out (LIFO) queue (aka. a stack)
- Also easy to implement recursively:
- DFS(node)
  - If goal(node) return solution(node);
  - For each successor of node
    - Return DFS(successor) unless it is *failure*;
  - Return *failure;*

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Properties of depth-first search

- Not complete (might cycle through nongoal states)
- If solution found, generally not optimal/shallowest
- If every node has b successors (the branching factor), and we search to at most depth m, fringe is at most bm
  - Much better space requirement ☺
  - Actually, generally don't even need to store all of fringe
- Time: still need to look at every node
  - $b^m + b^{m-1} + \ldots + 1$ (for $b>1$, $O(b^m)$)
  - Inevitable for uninformed search methods…

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Combining good properties of BFS and DFS

- Limited depth DFS: just like DFS, except never go deeper than some depth d
- Iterative deepening DFS:
  - Call limited depth DFS with depth 0;
  - If unsuccessful, call with depth 1;
  - If unsuccessful, call with depth 2;
  - Etc.
- Complete, finds shallowest solution
- Space requirements of DFS
- May seem wasteful timewise because replicating effort
  - Really not that wasteful because **almost all effort at deepest level**
  - $db + (d-1)b^2 + (d-2)b^3 + ... + 1b^d$ is $O(b^d)$ for $b > 1$

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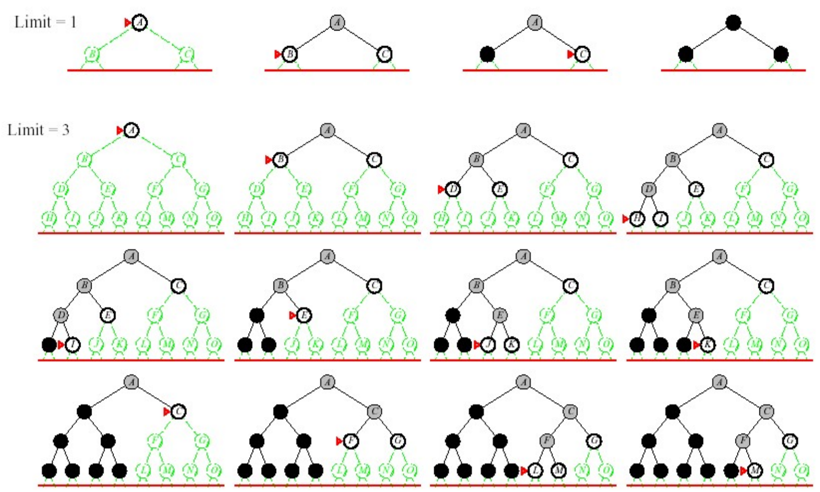

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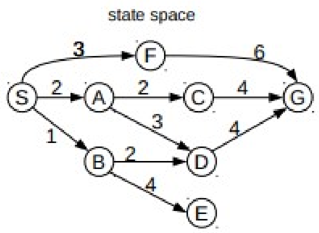
Example 1



heuristic function (goal state: G)

S	A	B	C	D	E	F	G
6	4	5	2	2	8	4	0

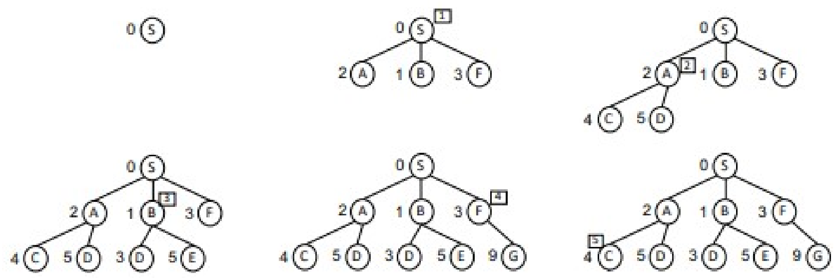
–States are denoted by letters

–The cost of each action is indicated on the corresponding edge.

–Actions are not reversible, since the graph is oriented.

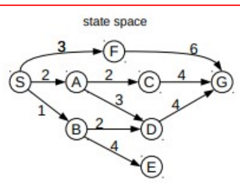
Example 1

- Considering S as the initial state, solve the given search problem using breadth-first search



!!!The solution found by breadth-first search (S→F→G) is not the one with minimum path cost

This search strategy is not optimal

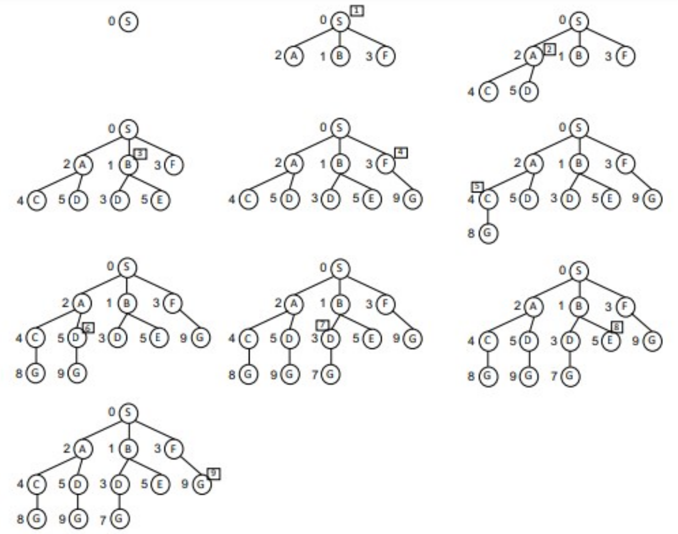


heuristic function (goal state: G)

S	A	B	C	D	E	F	G
6	4	5	2	2	8	4	0

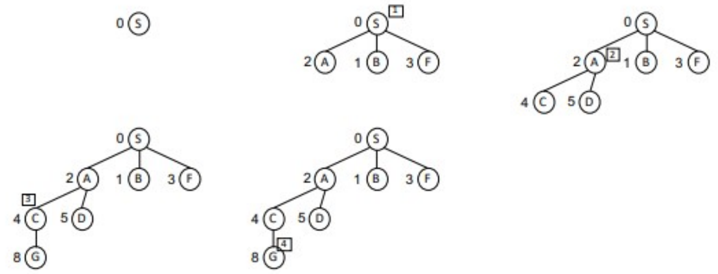
Example 1

- The full search tree built by breadth-first search



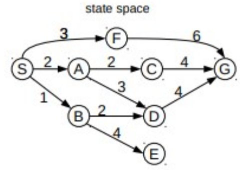
Example 1

- Considering S as the initial state, solve the given search problem using depth-first search



!!!The solution found by depth-first search (S→A→C → G) is not the one with minimum path cost

This search strategy is not optimal



heuristic function (goal state: G)

S	A	B	C	D	E	F	G
6	4	5	2	2	8	4	0

Example 2: the block's world

- The block's world is a well-known toy domain used in AI for planning problems related to robots.
- A set of blocks of various size, shape, and color, ..
- Blocks can be stacked into one or more piles, possibly with some constraints
- The goal is to form a target set of piles starting from a given initial configuration
- Moving one block at a time, either to the table or atop another pile of blocks, and only if it is not under another block.