Artificial & Computational Intelligence

AIML CLZG557

M2 : Problem Solving Agent using Search

Dr. Sudheer Reddy

BITS Pilani
Pilani Campus

Course Plan

M1 Introduction to AI

M2 Problem Solving Agent using Search

M3 Game Playing

M4 Knowledge Representation using Logics

M5 Probabilistic Representation and Reasoning

M6 Reasoning over time

M7 Ethics in AI

Module 2 : Problem Solving Agent using Search

A. Uninformed Search

B. Informed Search

C. Heuristic Functions

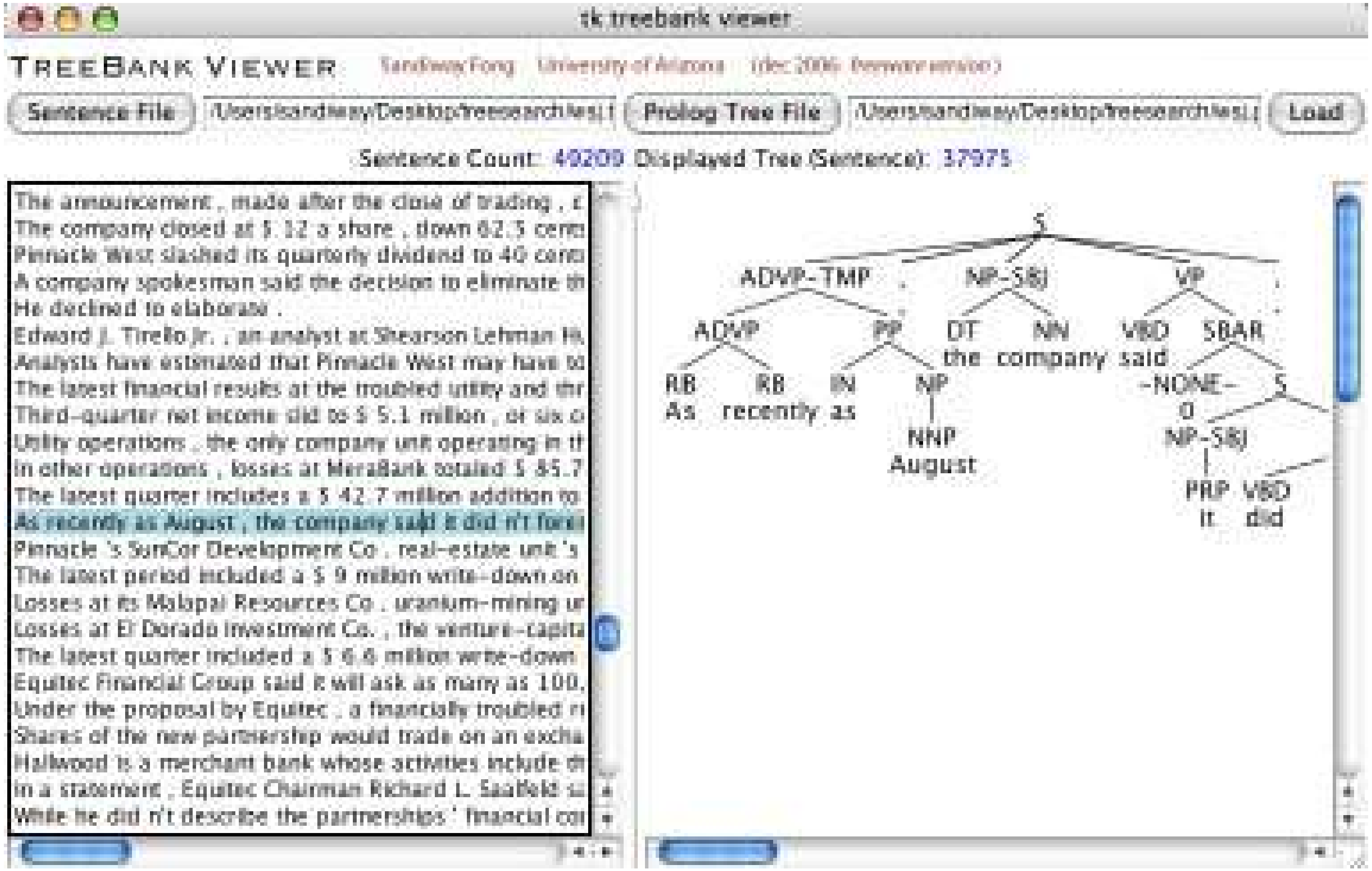
D. Local Search Algorithms & Optimization Problems

Learning Objective

At the end of this class , students Should be able to:

1. Apply A* variations algorithms to the given problem
2. Compare given heuristics for a problem and analyze which is the best fit
3. Differentiate between informed and local search requirements
4. Design relaxed problem with appropriate heuristic design

Case Study – 1 Search in Treebanks

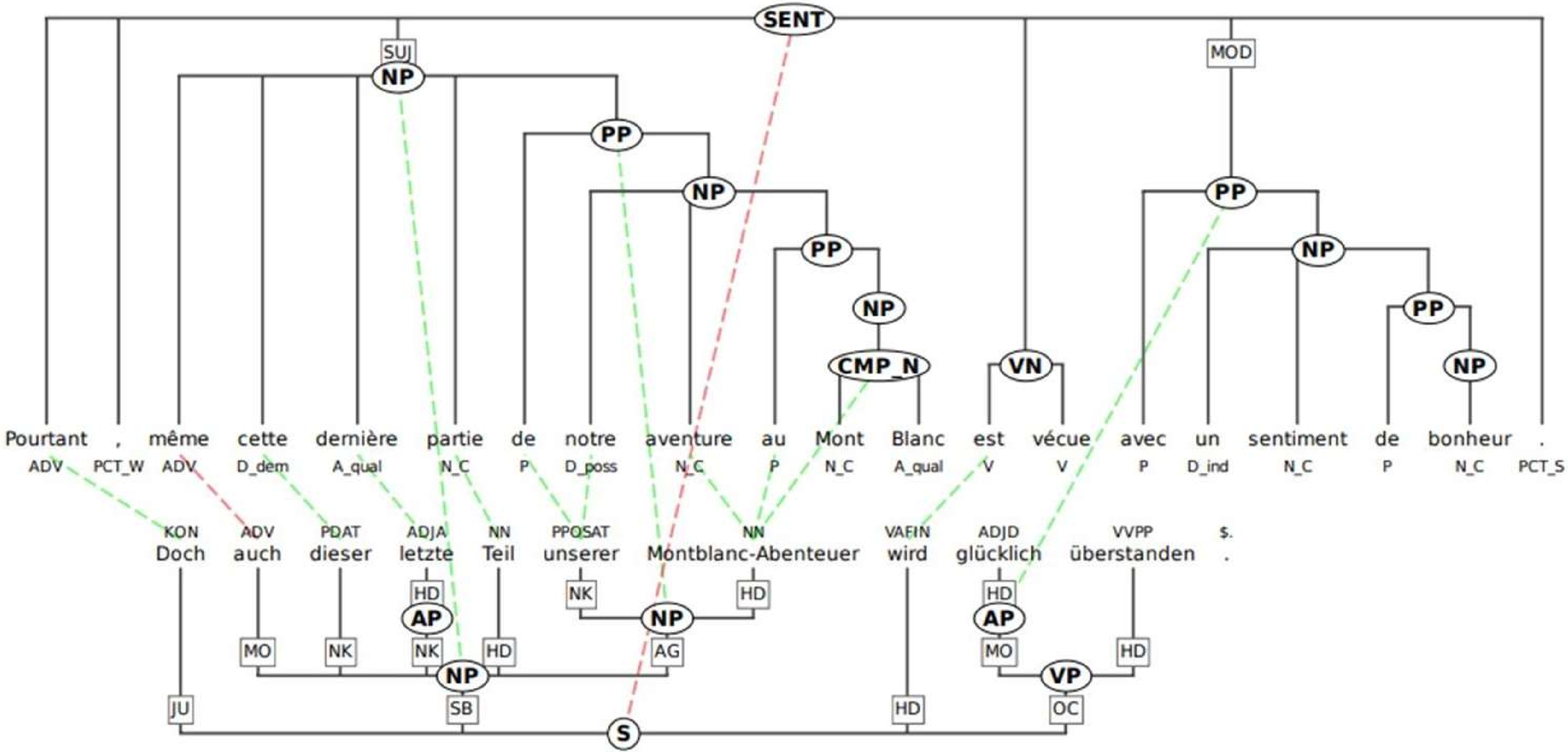


Source Credit :

https://catalog.ldc.upenn.edu/docs/LDC95T7/cl93.html

https://ufal.mff.cuni.cz/pdt3.5

Case Study – 1 Search in Treebanks



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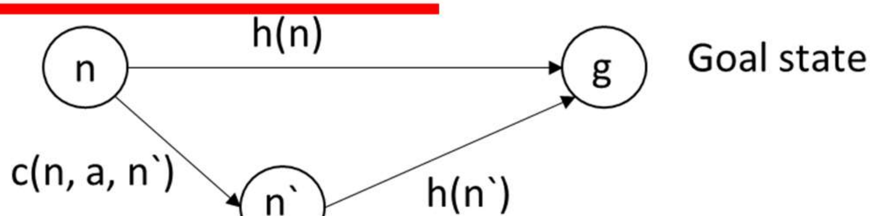
https://ufal.mff.cuni.cz/pdt3.5

A* Search



Optimal on condition

h(n) must satisfies two conditions:

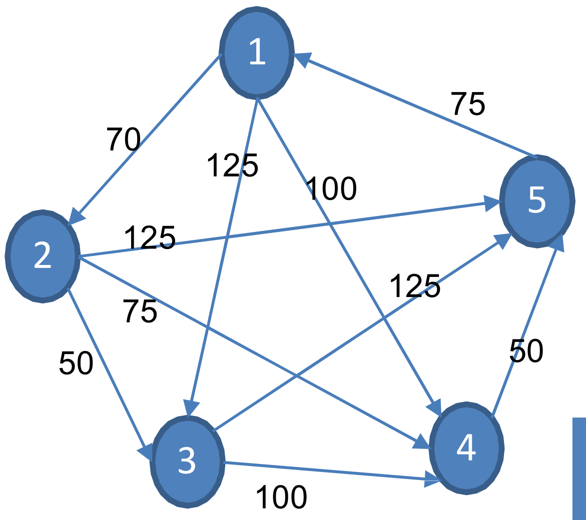
- Admissible Heuristic – one that never overestimates the cost to reach the goal
- Consistency – A heuristic is consistent if for every node n and every successor node n` of n generated by action a,  h(n) <= c(n, a, n`) + h(n`)

Complete

- If the number of nodes with cost <=C* is finite
- If the branching factor is finite
- A* expands no nodes with f(n) > C*, known as pruning

Time Complexity - $G\left(b^{\Delta}\right)$ where the absolute error $\Delta = h^{*} - h$

Is the heuristic designed leads to optimal solution?

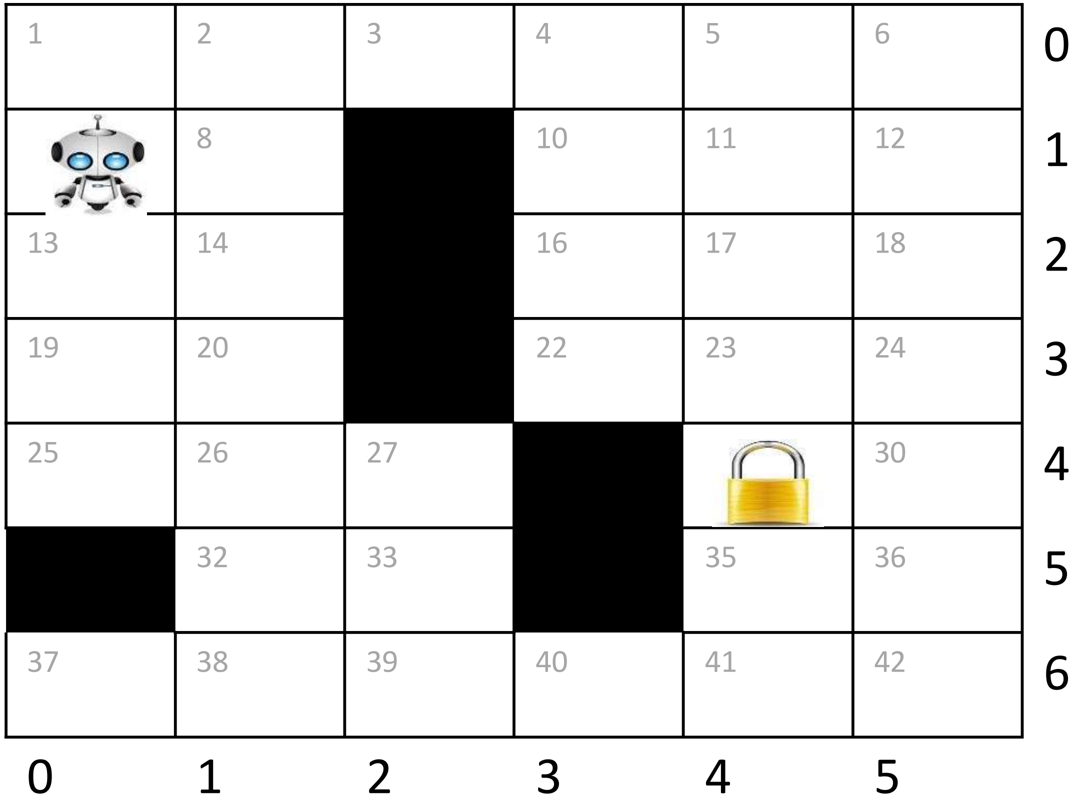


Assuming node 3 as goal, taking only sample edges per node below is checked for consistency

n	h(n)	Is Admissible? h(n) <= h*(n)	Is Consistent? For every arc (i,j): h(i) <= g(i,j) + h(j)
1	80	Y	N (5→1) : 190<=155
2	60	N	Y (1→2) : 80<=130
3	0	Y	
4	200	Y	Y (1→4) : 80<=300 Y (2→4) : 60<=275
5	190	Y	Y (2→5) : 60<=315 Y (4→5) : 200<=240

Path finding Robot – Sample Planning Agent Design

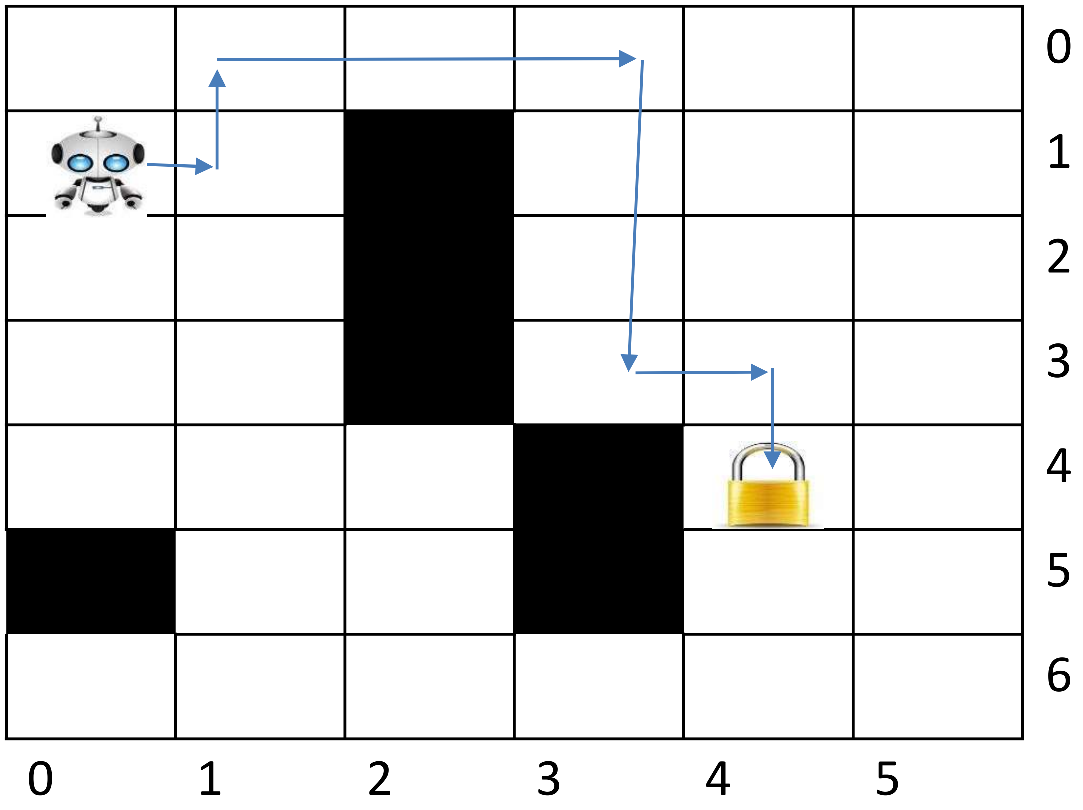
Successor Function Design



N-W-E-S

A*

Demo

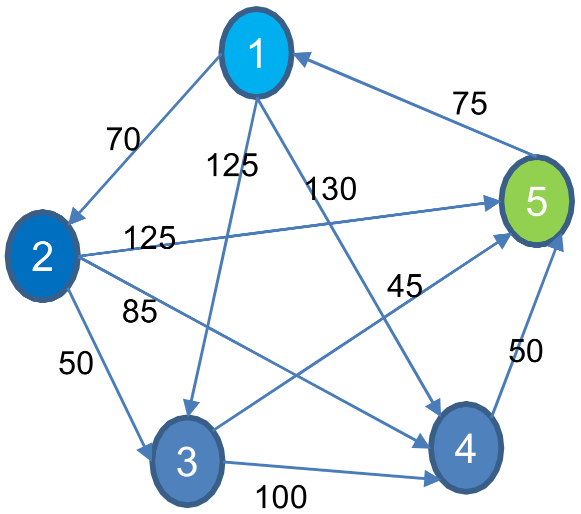


Variations of A*

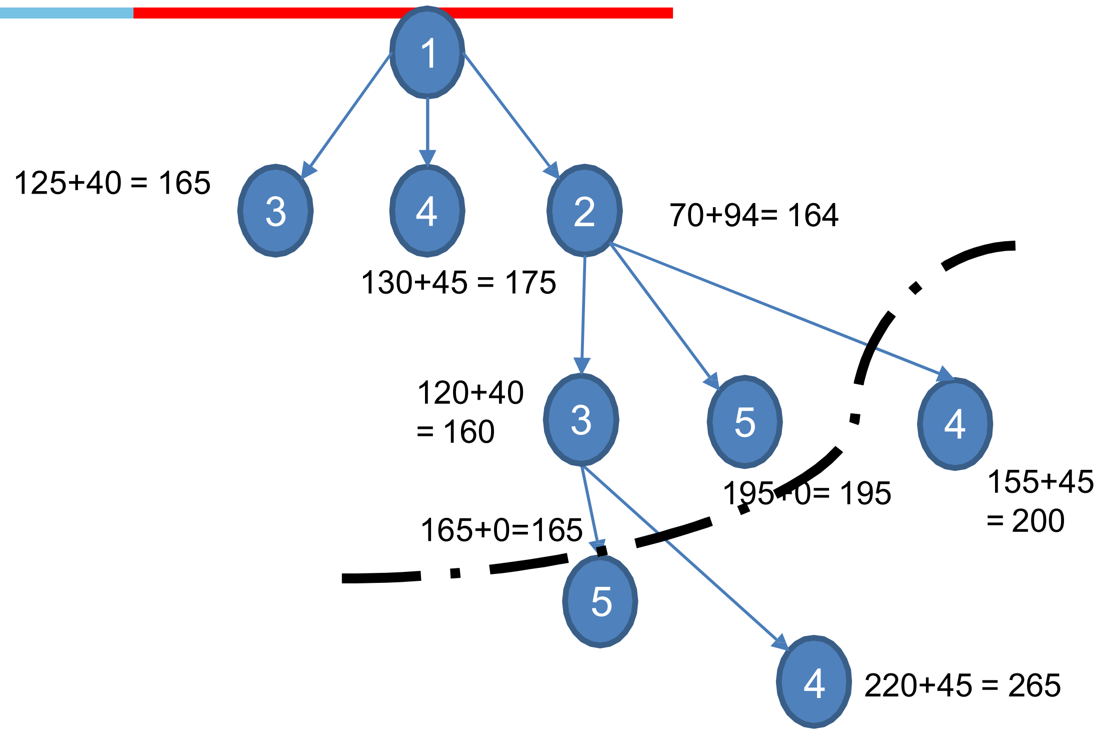
Memory Bounded Heuristics

Iterative Deepening A*

Set limit for f(n)



n	h(n)
1	60
2	94
3	40
4	45
5	0

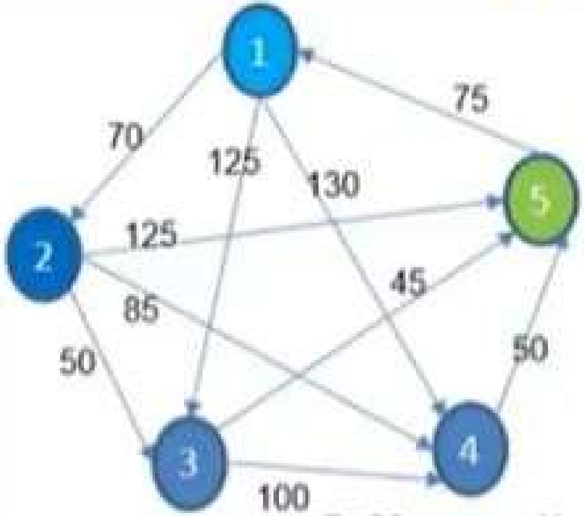


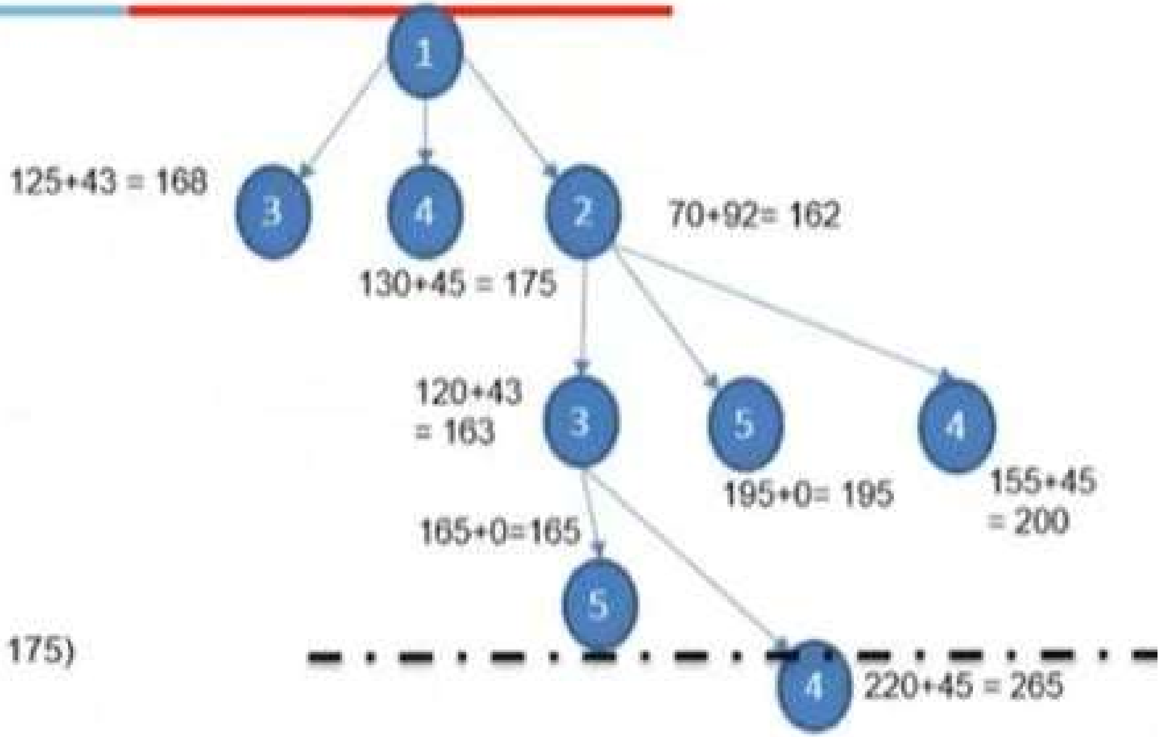
Cut off value is the smallest of f-cost of any node that exceeds the cutoff on previous iterations

Iterative Limit : Eg
f(n) = 180
f(n) = 195
f(n) = 200
.
.
.
.

Iterative Deepening A*

Set limit for f(n)





n	h(n)
1	60
2	92
3	43
4	45
5	0

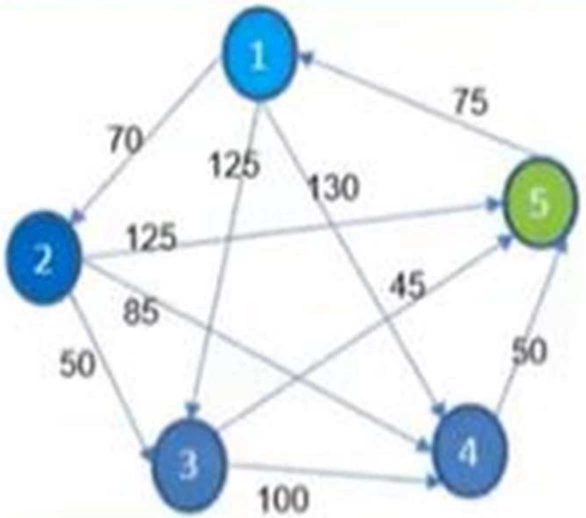
B=60
(1: 60)
TEST-F
(1 2: 162) (1 3: 168) (1 4: 175)

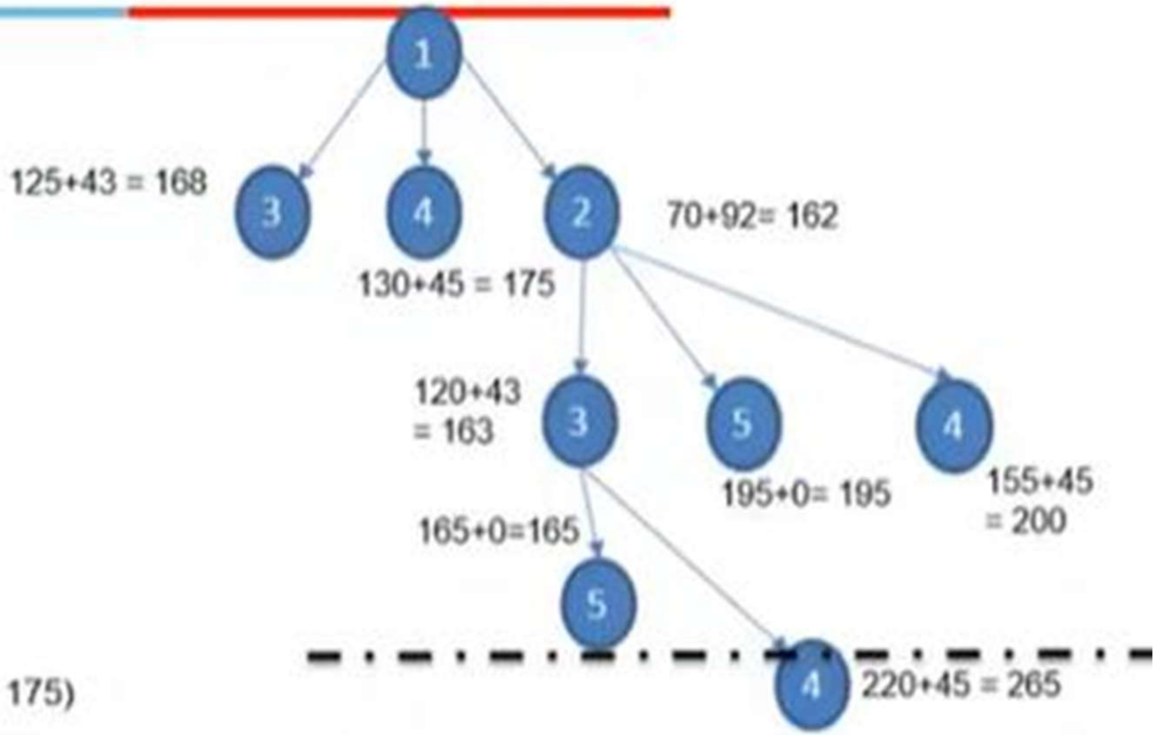
B=162
(1: 60)
TEST-F
(1 2: 162) (1 3: 168) (1 4: 175)
TEST-F
(1 2 3: 163) (1 2 4: 200) (1 2 5: 195) (1 3: 168) (1 4: 175)

B=163
(1: 60)
TEST-F
(1 2: 162) (1 3: 168) (1 4: 175)
TEST-F
(1 2 3: 163) (1 2 4: 200) (1 2 5: 195) (1 3: 168) (1 4: 175)
TEST-F

Iterative Deepening A*

Set limit for f(n)





n	h(n)
1	60
2	92
3	43
4	45
5	0

B=163

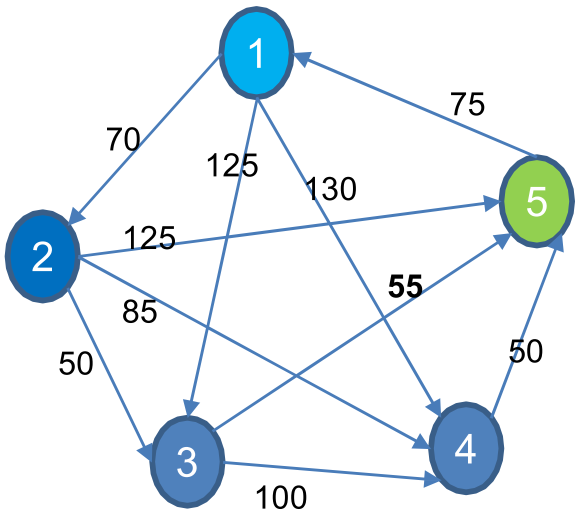
(1: 60)
TEST-F
(1 2: 162) (1 3: 168) (1 4: 175)
TEST-F
(1 2 3: 163) (1 2 4: 200) (1 2 5: 195) (1 3: 168) (1 4: 175)
TEST-F
(1 2 3 5: 165) (1 2 3 4: 265) (1 2 4: 200) (1 2 5: 195) (1 3: 168) (1 4: 175)

B=165

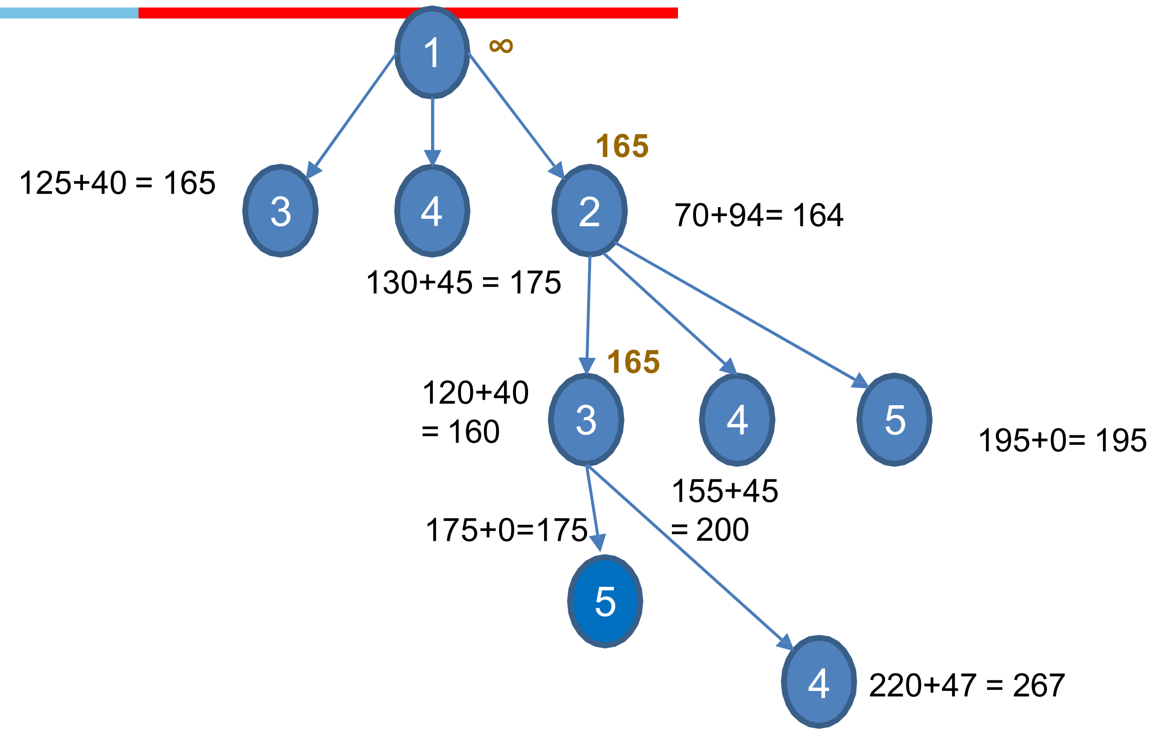
(1: 60)
TEST-F
(1 2: 162) (1 3: 168) (1 4: 175)
TEST-F
(1 2 3: 163) (1 2 4: 200) (1 2 5: 195) (1 3: 168) (1 4: 175)
TEST-F
(1 2 3 5: 165) (1 2 3 4: 265) (1 2 4: 200) (1 2 5: 195) (1 3: 168) (1 4: 175)

Recursive Best First Search A*

Remember the next best alternative f-Cost to regenerate



n	h(n)
1	60
2	94
3	40
4	45
5	0



(1, 60)

(1 2 | 164) (1 3 | 165) (1 4 | 175)

(1 2 | 175) (1 4 | 175) (1 3 | 180)

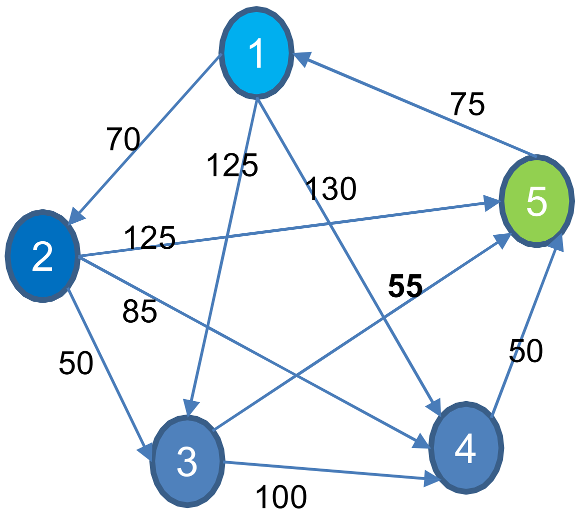
(1 2 3 | 175) (1 4 | 175) (1 3 | 180) (1 2 5 | 195) (1 2 4 | 200)

(1 2 3 5 | 175) (1 4 | 175) (1 3 | 180) (1 2 5 | 195) (1 2 4 | 200) (1 2 3 4 | 267)

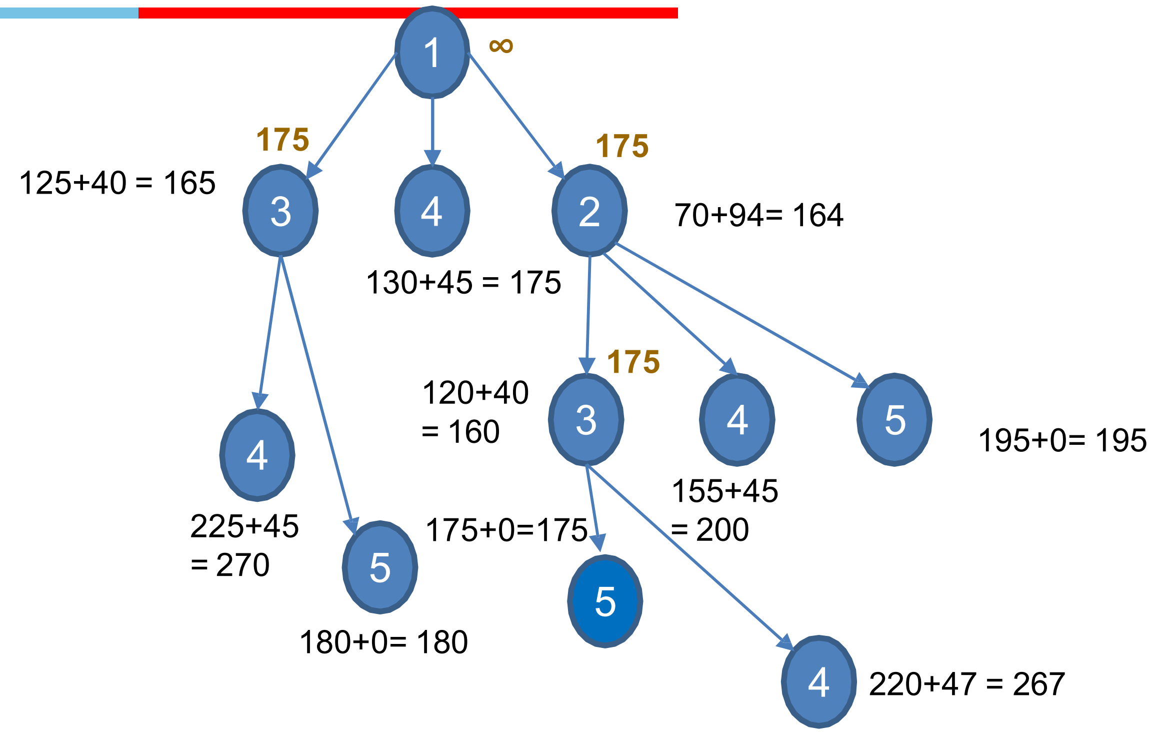
PASS

Recursive Best First Search A*

Remember the next best alternative f-Cost to regenerate



n	h(n)
1	60
2	94
3	40
4	45
5	0



(1, 60)

(1 2 | 164) (1 3 | 165) (1 4 | 175)

(1 2 | 175) (1 4 | 175) (1 3 | 180)

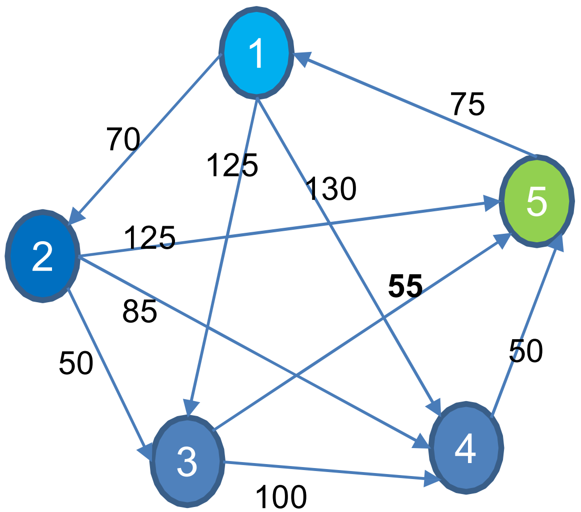
(1 2 3 | 175) (1 4 | 175) (1 3 | 180) (1 2 5 | 195) (1 2 4 | 200)

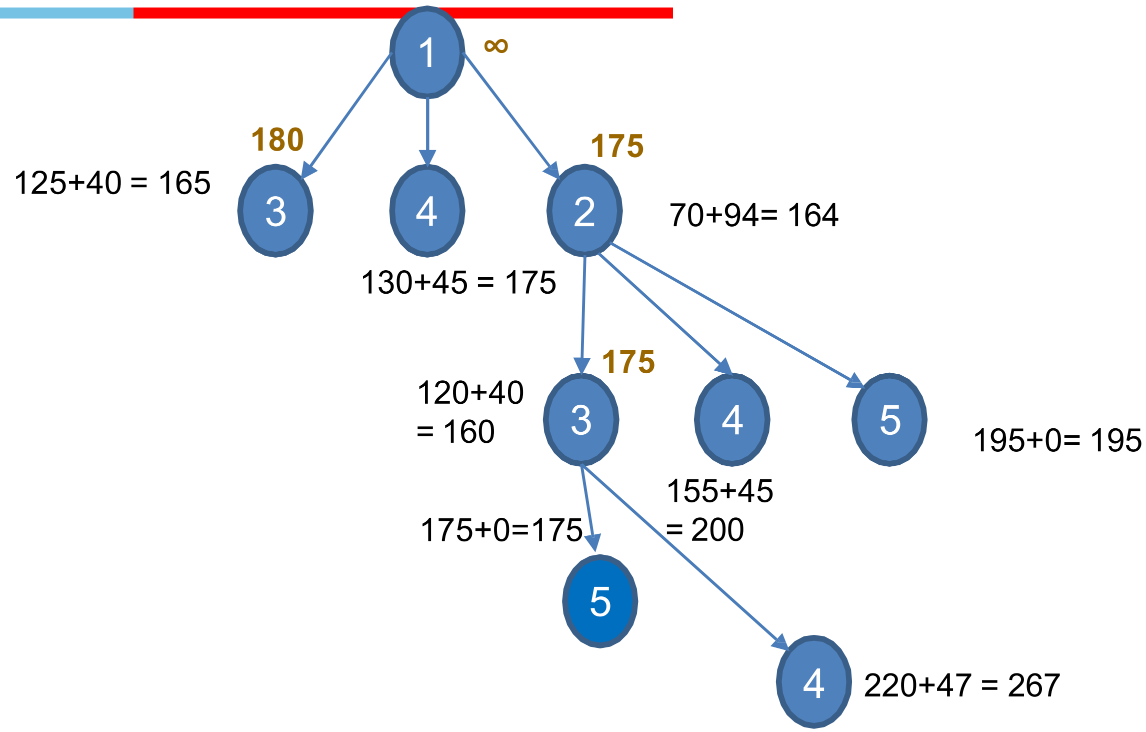
(1 2 3 5 | 175) (1 4 | 175) (1 3 | 180) (1 2 5 | 195) (1 2 4 | 200) (1 2 3 4 | 267)

PASS

Recursive Best First Search A*

Remember the next best alternative f-Cost to regenerate





n	h(n)
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(1, 60)

(1 2 | 164) (1 3 | 165) (1 4 | 175)

(1 2 | 175) (1 4 | 175) (1 3 | 180)

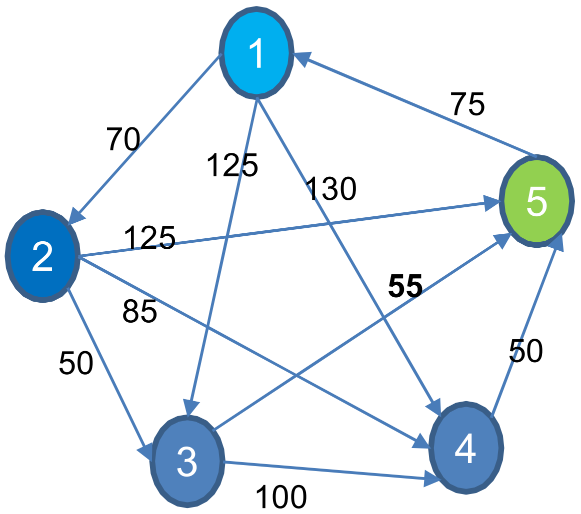
(1 2 3 | 175) (1 4 | 175) (1 3 | 180) (1 2 5 | 195) (1 2 4 | 200)

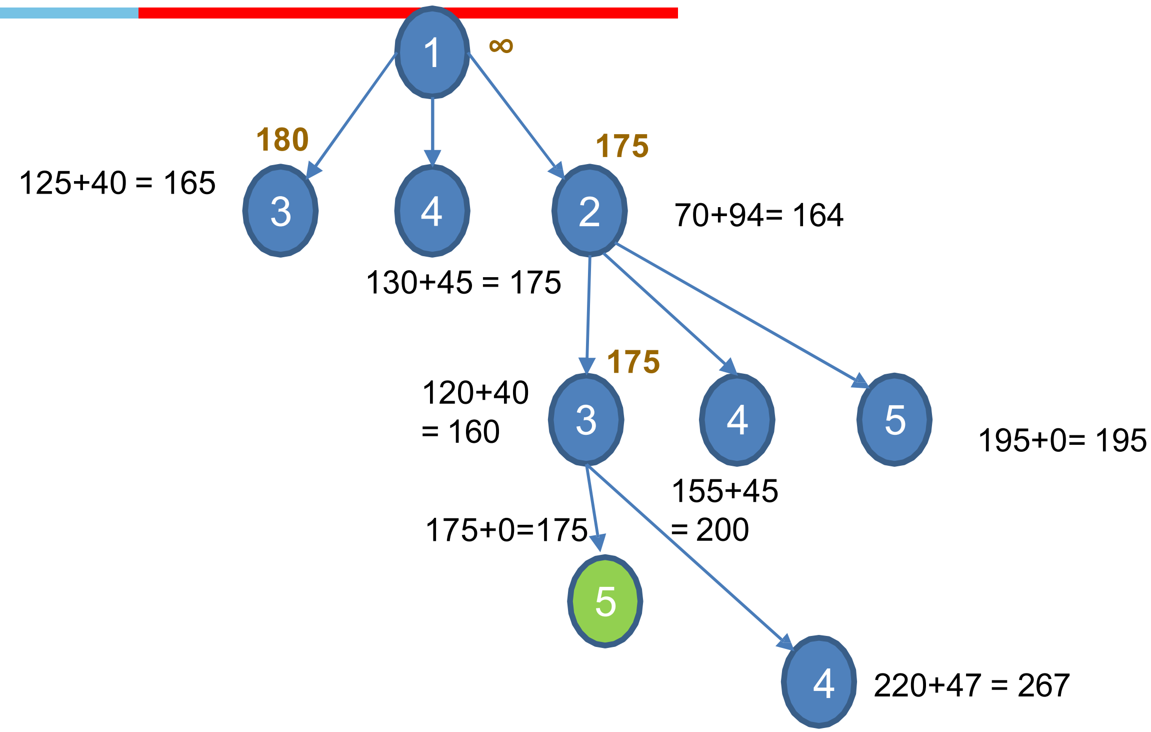
(1 2 3 5 | 175) (1 4 | 175) (1 3 | 180) (1 2 5 | 195) (1 2 4 | 200) (1 2 3 4 | 267)

PASS

Recursive Best First Search A*

Remember the next best alternative f-Cost to regenerate





n	h(n)
1	60
2	94
3	40
4	45
5	0

If the current best leaf value > best alternative path

Best leaf value of the forgotten subtree is backed up to the ancestors

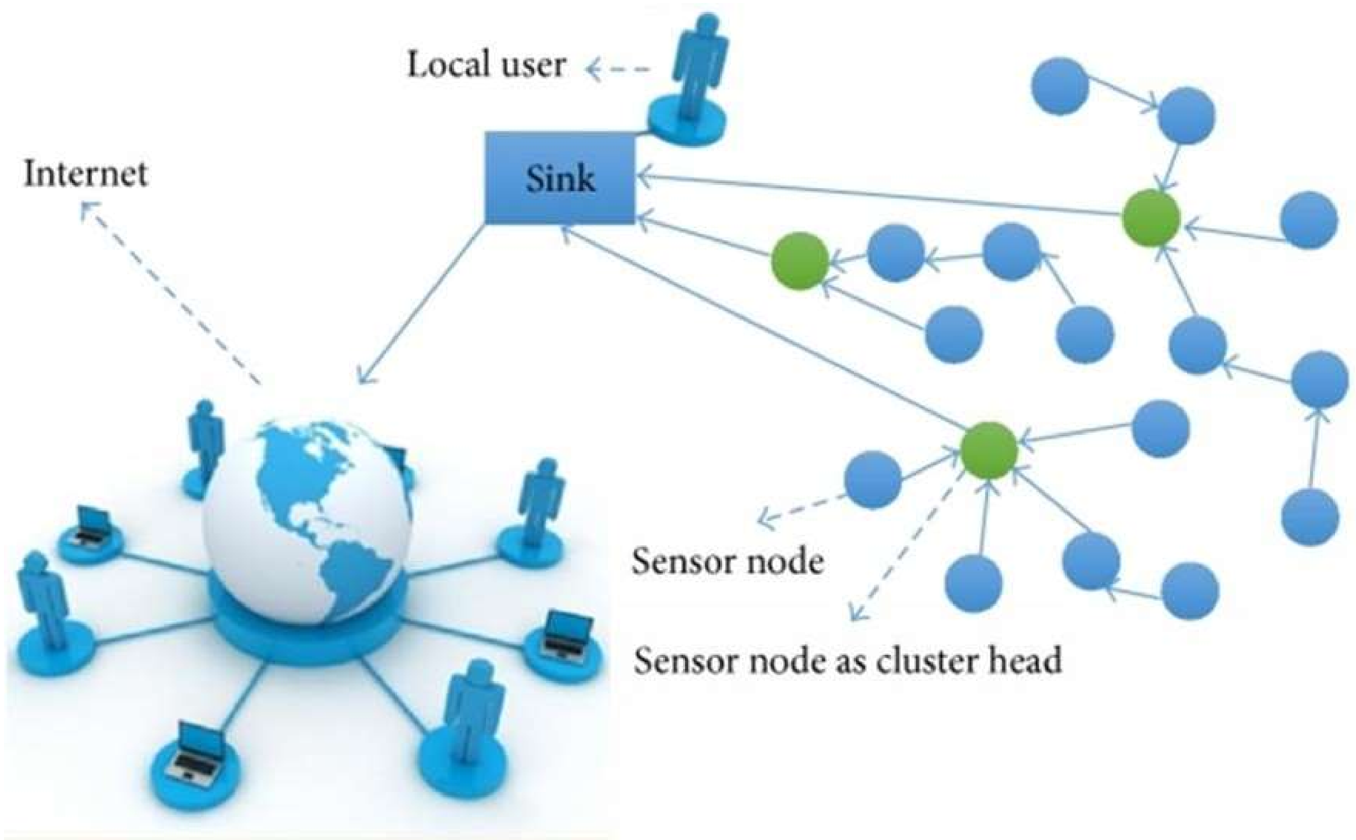
Recursion unwinds

Else

Continue expansion

Space Usage = O(bd) very less

Case Study – Search in Network Routing

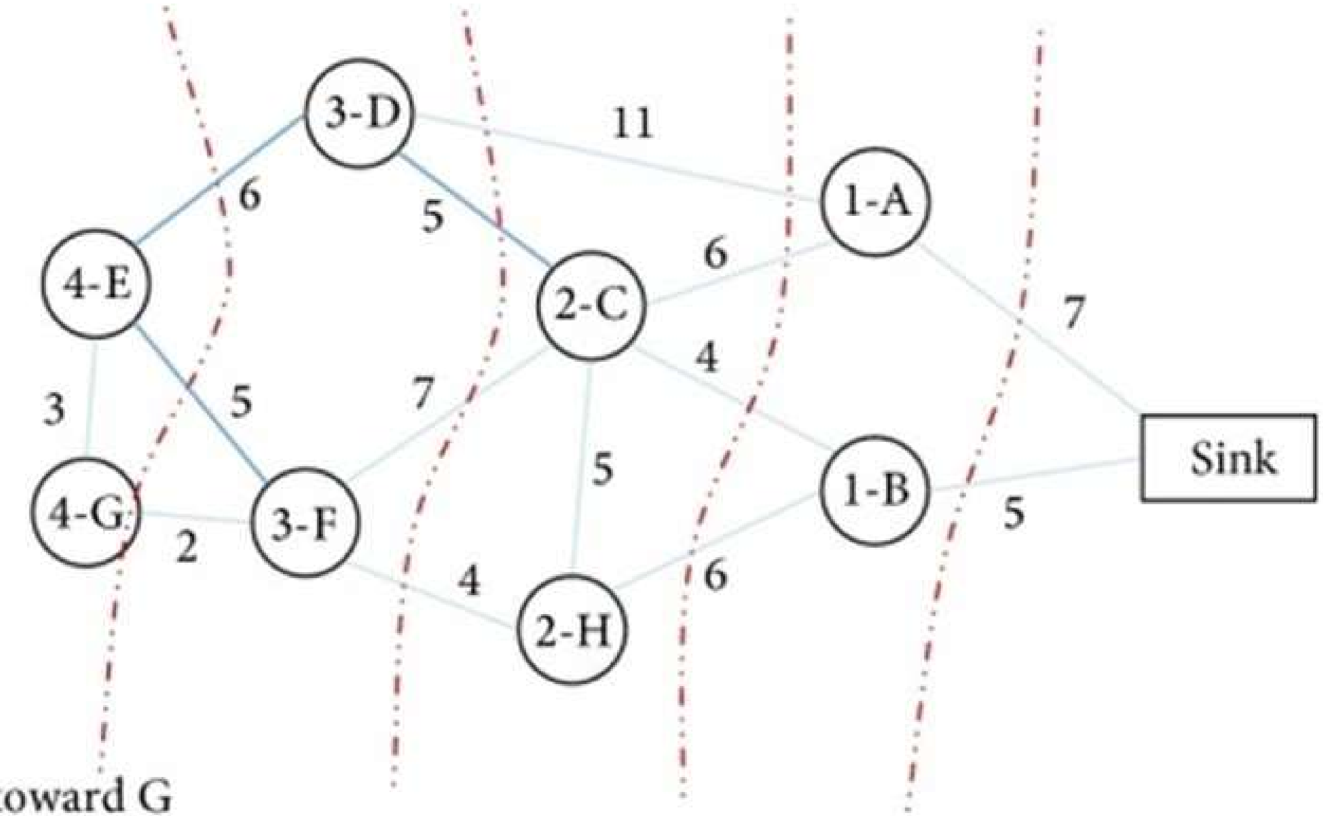


Source Credit :

AR-RBFS: Aware-Routing Protocol Based on Recursive Best-First Search Algorithm for Wireless Sensor Networks
https://doi.org/10.1155/2016/8743927

Case Study – Search in Network Routing

A	14.1
B	11.3
C	8.2
H	6.6
F	2
E	3
D	4.8



Heuristic values toward G

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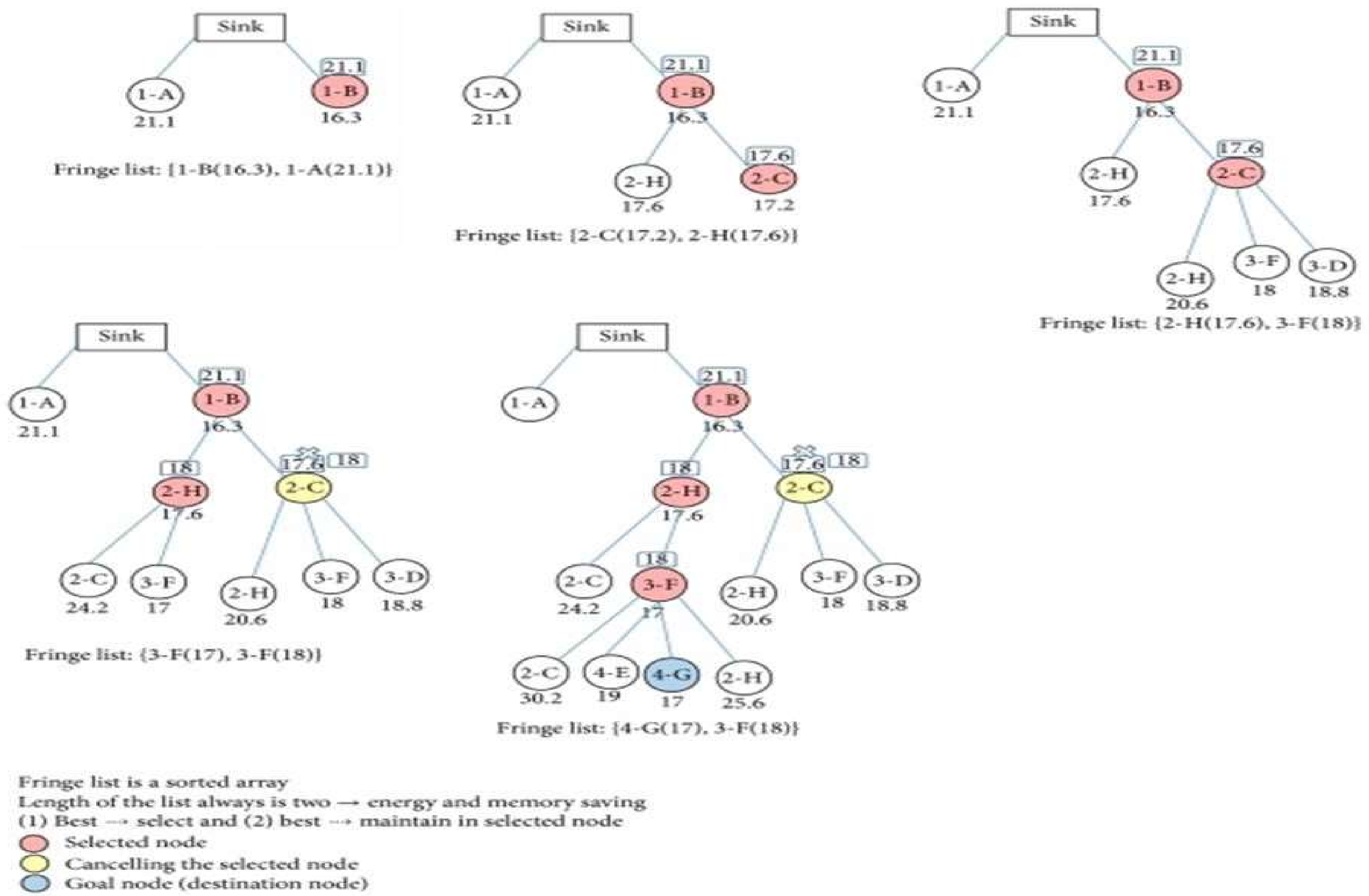

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Design of Heuristics

Heuristic Design

- **Effective Branching Factor**
- Good Heuristics
- Notion of Relaxed Problems
- Generating Admissible Heuristics

Effective branching factor (b^*):

If the algorithm generates N number of nodes and the solution is found at depth d, then

$$N + 1 = 1 + (b^*) + (b^*)^2 + (b^*)^3 + \ldots + (b^*)^d$$

Heuristic Design

- Effective Branching Factor
- Good Heuristics
- **Notion of Relaxed Problems**
- Generating Admissible Heuristics

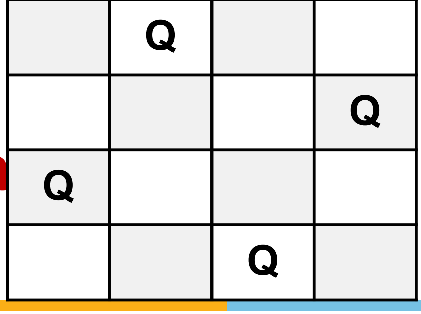
Simplify the problem

Assume no constraints

Cost of optimal solution to relaxed problem ≤ Cost of optimal solution for real problem

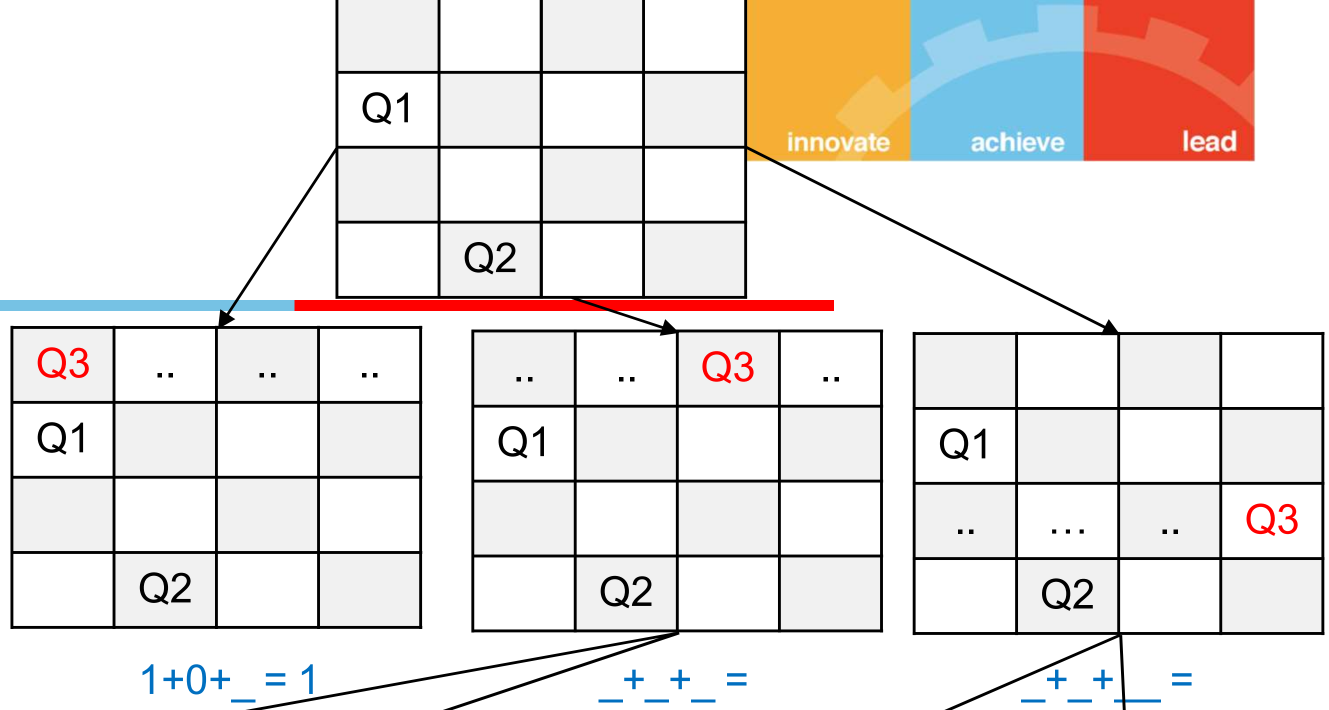
Design of Heuristics

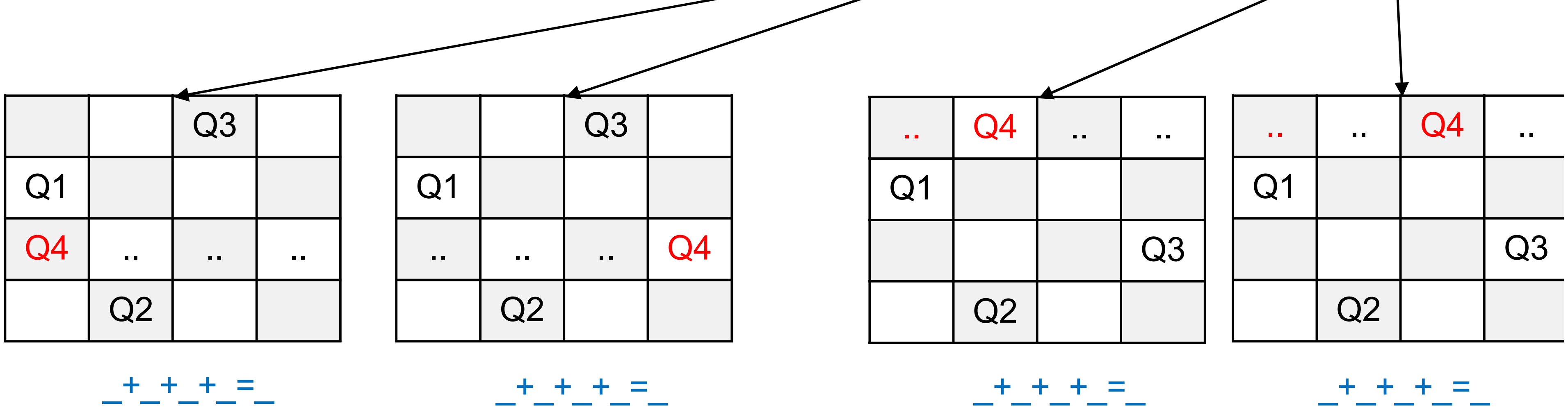
N-Queen



innovate achieve lead

- ➢Construct the search tree by considering one row of the board at a time
- ➢ State space graph of relaxed problem is a super graph of original state space because of removal of restrictions

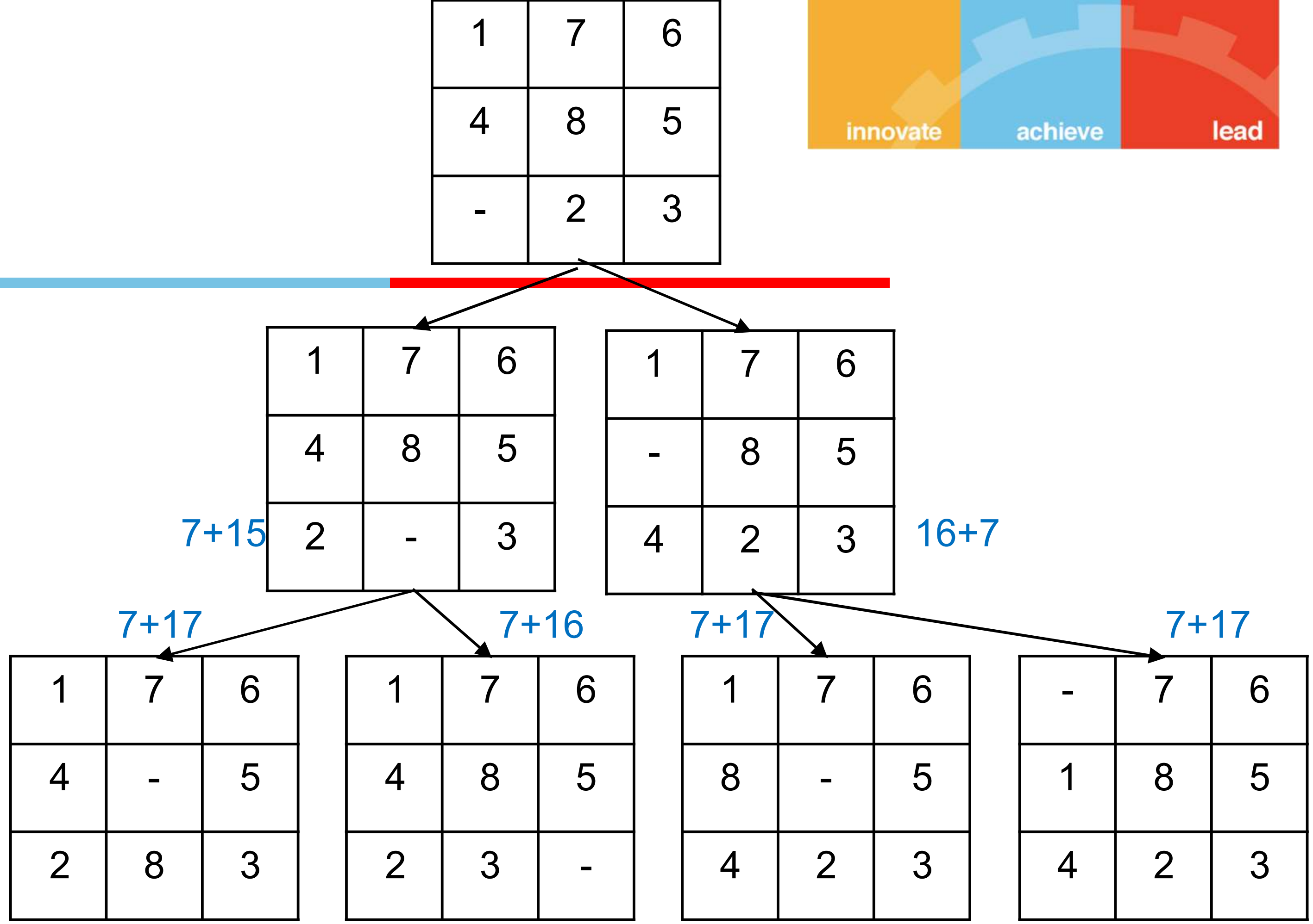




Initial State	Possible Actions	Transition Model	Goal Test	Path Cost	No.Of.States
< Xi , Yi >	Place in any non-occupied row in board		isValid Non-Attacking	Transition + Valid Queens	n!

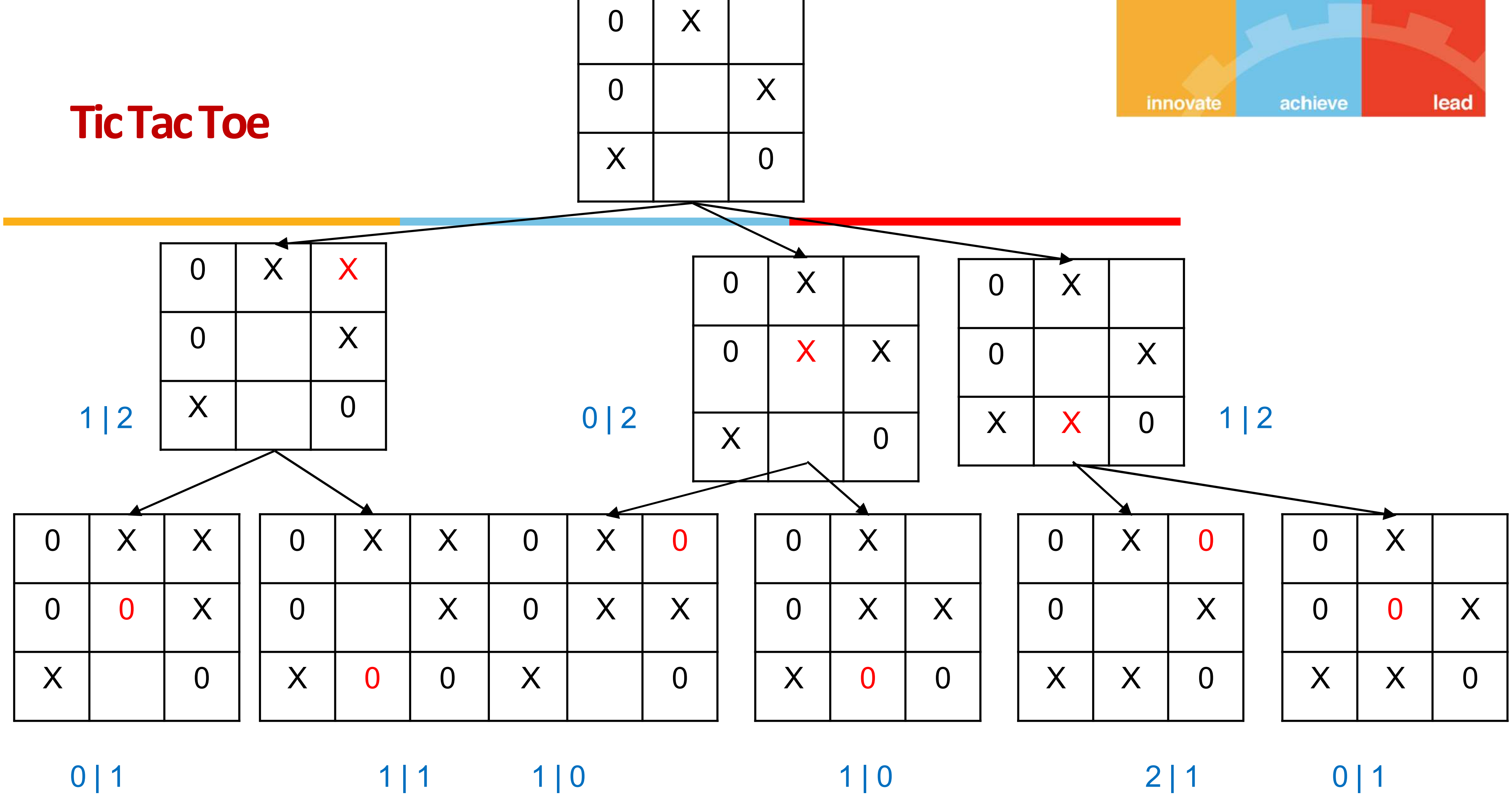
N-Tile

-	1	2
3	4	5
6	7	8



Initial State	Possible Actions	Transition Model	Goal Test	Path Cost	No.Of.States
<LOC, ID>	Move Empty to near by Tile		ID=LOC+1	Transition + Positional + Distance+ Other approaches	9!

Tic Tac Toe



Opposite Win | Player Win

Initial State	Possible Actions	Transition Model	Goal Test	Path Cost	No.Of.States
([Xij], [Yij])	Place a coin in unoccupied (i,j)		N : i's N : j's N : i=j	No.of.Steps + Opp.Win + (N-1-Curr.Win)	19,683=3^9

Learn from experience

Trail / Puzzle	X1(n) : No.of.Misplaced Tiles	X2(n): Pair of adjacent tiles that are not in goal	X3(n): Position of the empty tile	…………h`(n)
Example 1	7	10	7	…………
Example 2	5	6	6	…………
………	..	..	..	…………

-	1	2
3	4	5
6	7	8

1	7	6
4	8	5
-	2	3

Create a suitable model:
h(n) = c1*X1(n) + c2*X2(n) + ……….

Required Reading: AIMA - Chapter #3: 3.5, 3.6

Next Class Plan :
Local Search Algorithms &
Optimization Problems

Thank You for all your Attention

Note : Some of the slides are adopted from AIMA TB materials