

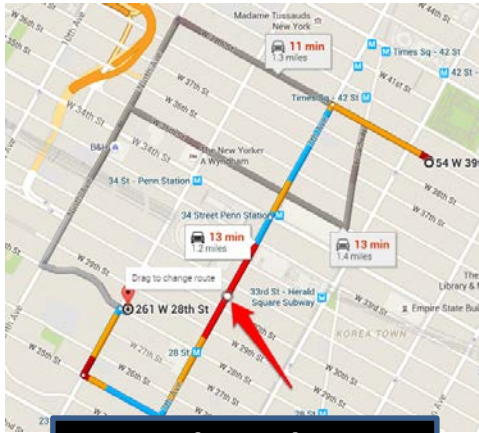
SEARCH METHODS IN AI

AUTOMATED PROBLEM SOLVING



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Indian Institute of Technology Kharagpur

COMPLEX PROBLEMS & SOLUTIONS



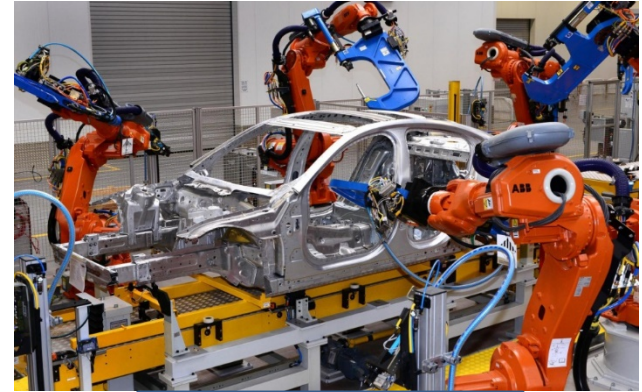
Path Finding

Map, locations
streets, start
goal,



Chess Playing

Board, pieces,
moves, players
Start, goal
(win/loss, draw)

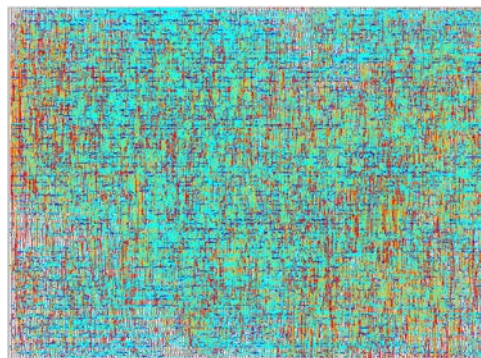


Robot Assembly

robot → actions
↳ scene analysis
↳ coordinated
series of actions



COMPLEX PROBLEMS & SOLUTIONS



VLSI Chip Design

components
connected by wires
billions of components
placement, routing
optimization

Example 1 - Prime Timetabl x

www.primetimetable.com/Application/?demo#id=69e5bf8d-74a5-4984-b9

Loading maker 78%

	Monday						Tuesday					
	1	2	3	4	5	6	1	2	3	4	5	
5-A	PE	Mus		TW	Eng		Mat	His	Eng	Bio	Fre	
5-B	Eng	Geo	PE	Fre	Mat		Bio	Eng	PE	Fre	Pal	
5-C	Geo	Eng	Mat	Pal	Bio		Pal	Mat	Bio	Mus	Eng	
5-D		TW		Mus	Eng	PE	Ger	Geo	Bio	Pal	Eng	
7-A	Che	PE	Mat	Geo	Mus		Ger	Pal	Mat	Eng	PE	
7-B	Geo	PE	His	Bio	Ger		Mus	PE	Che	Mat	His	
7-C	PE	Phy	Geo	Mat	Fre			TW	Mat	Pal	Phy	
7-D	Mus	Mat	Eng	Phy	His		PE	Che	Fre	Geo	Bio	
7-E	Eng	Bio	Che	PE	Phy	Fre	Che	Mat	His	Phy	Eng	

Time-Table Scheduling

schedule/allocate
classes to rooms,
timeslots, teachers,
students

In Exercises 43–46, evaluate the definite integral by hand. Then use a symbolic integration utility to evaluate the definite integral. Briefly explain any differences in your results.

43. $\int_{-1}^2 \frac{x}{x^2 - 9} dx$

44. $\int_2^3 \frac{x+1}{x^2 + 2x - 3} dx$

45. $\int_0^3 \frac{2e^x}{2 + e^x} dx$

46. $\int_1^2 \frac{(2 + \ln x)^3}{x} dx$

Symbolic Integration

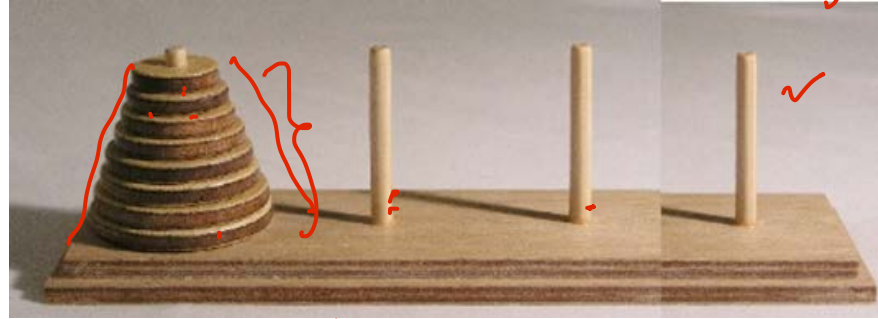
$\int (x^2 + 3x + 5) dx$
rules ✓
↓
final

AUTOMATED PROBLEM SOLVING BY SEARCH

- Generalized Techniques for Solving Large Classes of Complex Problems ✓
- Problem Statement is the Input and solution is the Output, sometimes even the problem specific algorithm or method could be the Output
- Problem Formulation by AI Search Methods consists of the following key concepts
 - Configuration or State ✓
 - Constraints or Definitions of Valid Configurations ✓
 - Rules for Change of State and their Outcomes ✓
 - Initial or Start Configurations ✓
 - Goal Satisfying Configurations ✓
 - An Implicit State or Configuration Space →
 - Valid Solutions from Start to Goal in the State Space ✓
 - General Algorithms which SEARCH for Solutions in this State Space
- **ISSUES** ✓
 - Size of the Implicit Space, Capturing Domain Knowledge, Intelligent Algorithms that work in reasonable time and Memory, Handling Incompleteness and Uncertainty

TOWER OF HANOI (Brahma)

- Configuration or State
- Constraints or Definitions of Valid Configurations
- Rules for Change of State and their Outcomes
- Initial or Start Configurations
- Goal Satisfying Configurations
- An Implicit State or Configuration Space
- Valid Solutions from Start to Goal in the State Space
- General Algorithms which SEARCH for Solutions in this State Space



$1, \dots, n$ A A D D

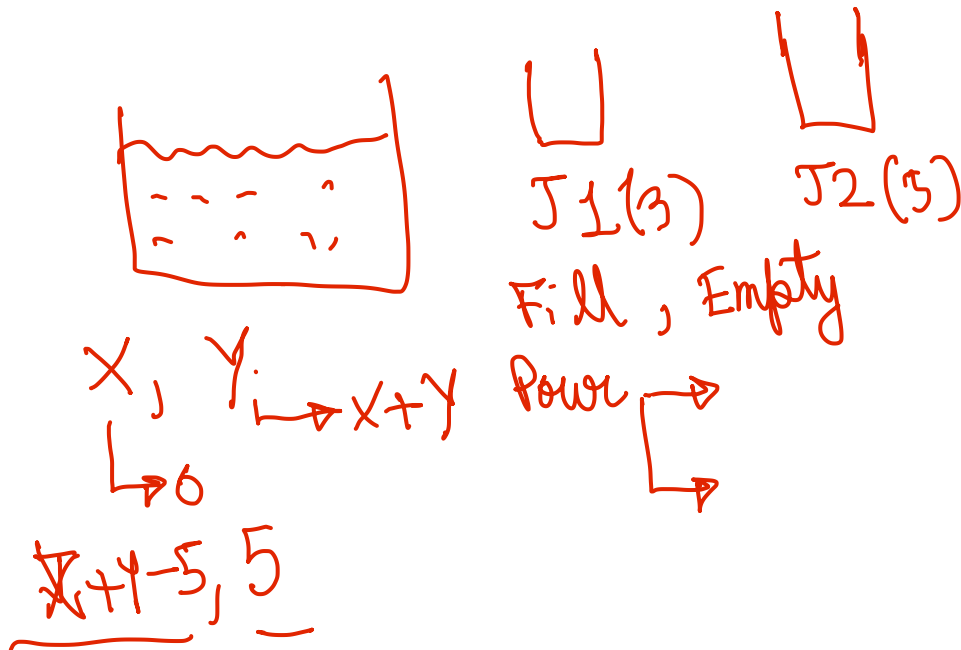
never should a larger disk be placed above a smaller disk

Configuration / state :- which disk is on top of which disk on which peg

rules $\rightarrow$ moving the topmost disk from one peg to another

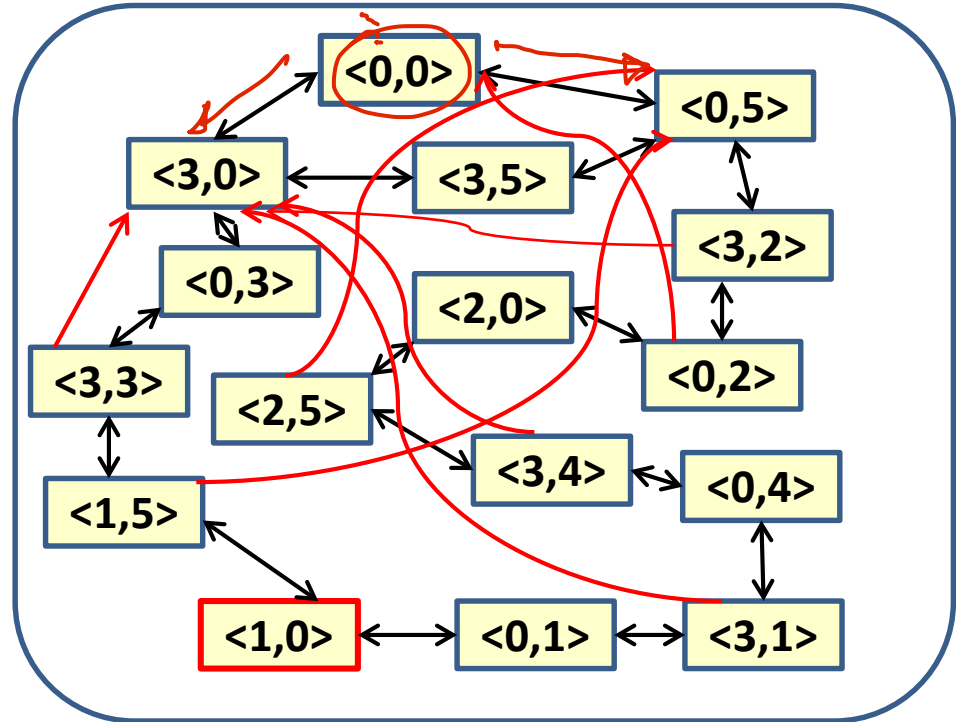
TWO JUG PROBLEM

- There is a large bucket B full of water and Two (02) jugs, J1 of volume 3 litre and J2 of volume 5 litre. You are allowed to fill up any empty jug from the bucket, pour all water back to the bucket from a jug or pour from one jug to another. The goal is to have jug J1 with exactly one (01) litre of water
- State Definition: $\langle J1, J2 \rangle$
- Rules:
 - Fill (J1): $\langle J1, J2 \rangle$ to $\langle 3, J2 \rangle$
 - Fill (J2): $\langle J1, J2 \rangle$ to $\langle J1, 5 \rangle$
 - Empty (J1), Empty (J2): Similarly defined
 - Pour (J1, J2): $\langle J1, J2 \rangle$ to $\langle X, Y \rangle$, where
 - $X = 0$ and $Y = J1 + J2$ if $J1 + J2 \leq 5$,
 - $Y = 5$ and $X = (J1 + J2) - 5$, if $J1 + J2 > 5$
 - Pour (J2, J1): Similarly defined
- Start: $\langle 0, 0 \rangle$, Goal: $\langle 1, 0 \rangle$
- Part of State Space Shown on the right
(Not all Links shown here)

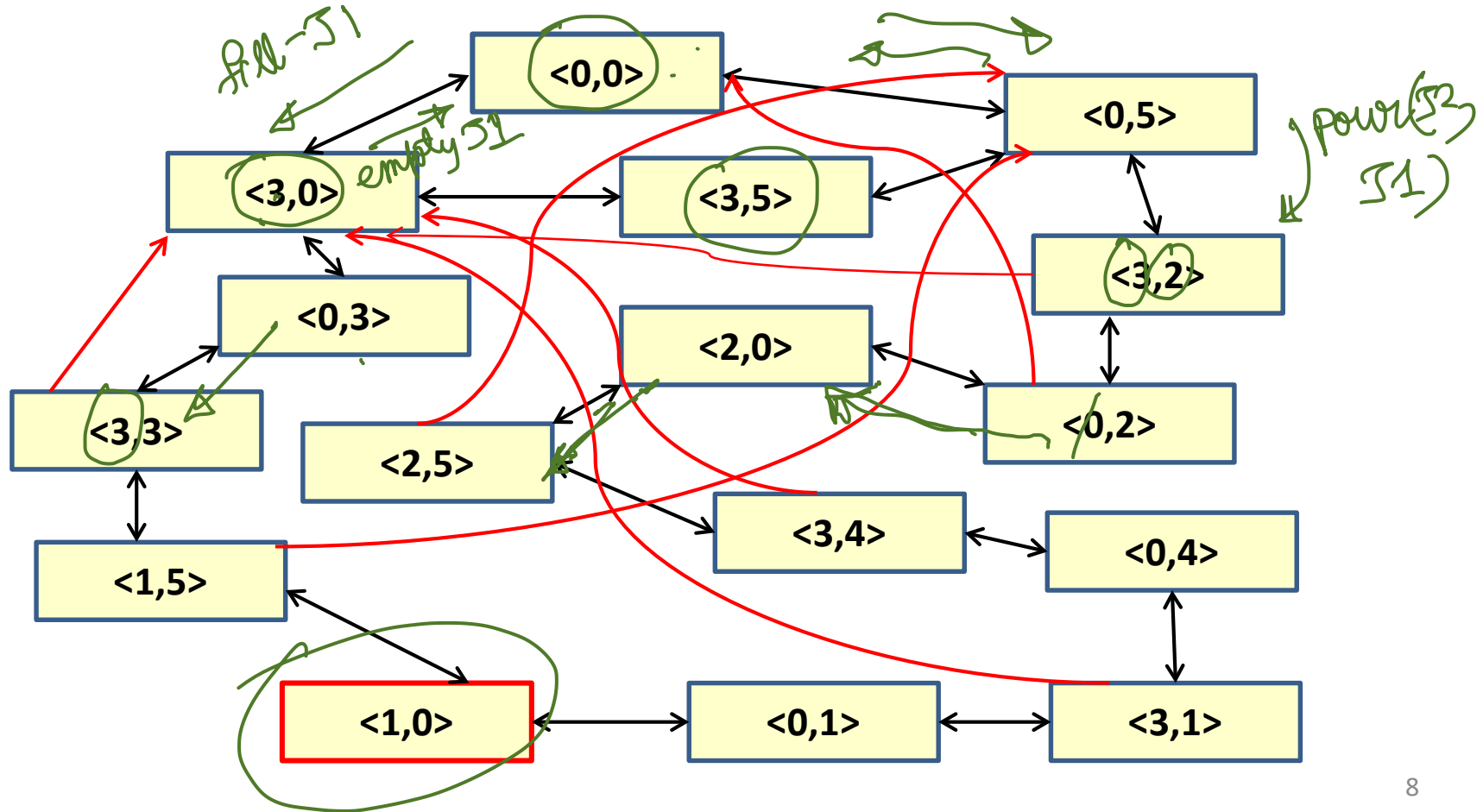


TWO JUG PROBLEM

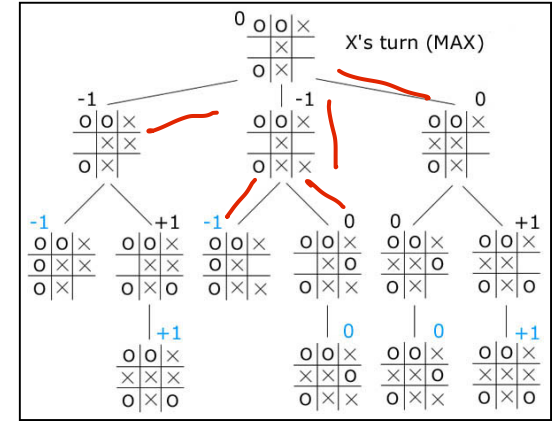
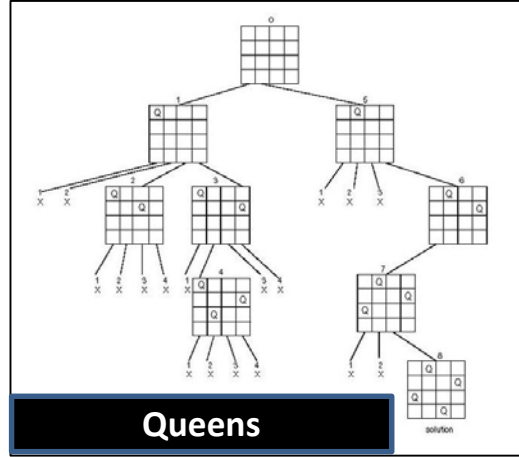
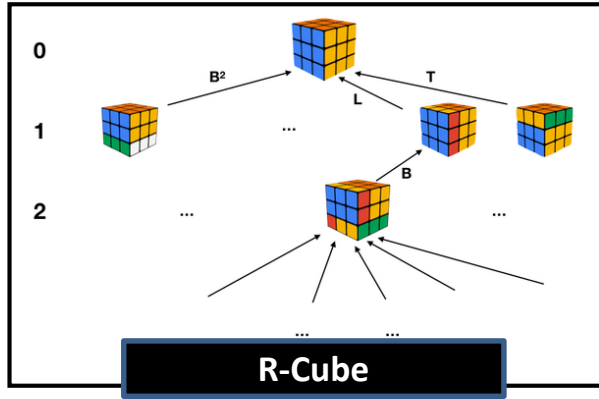
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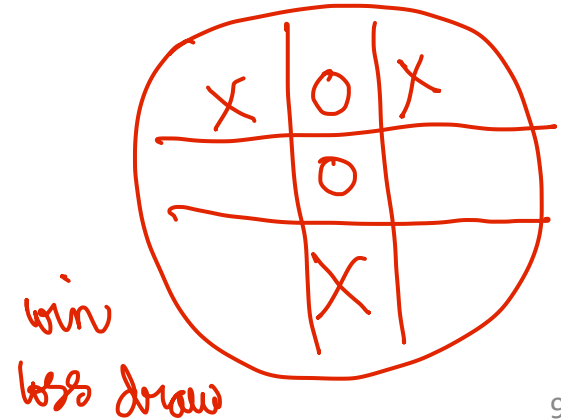
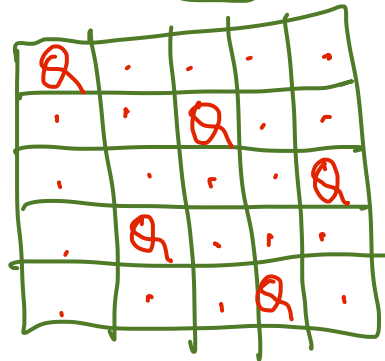
PART OF STATE SPACE



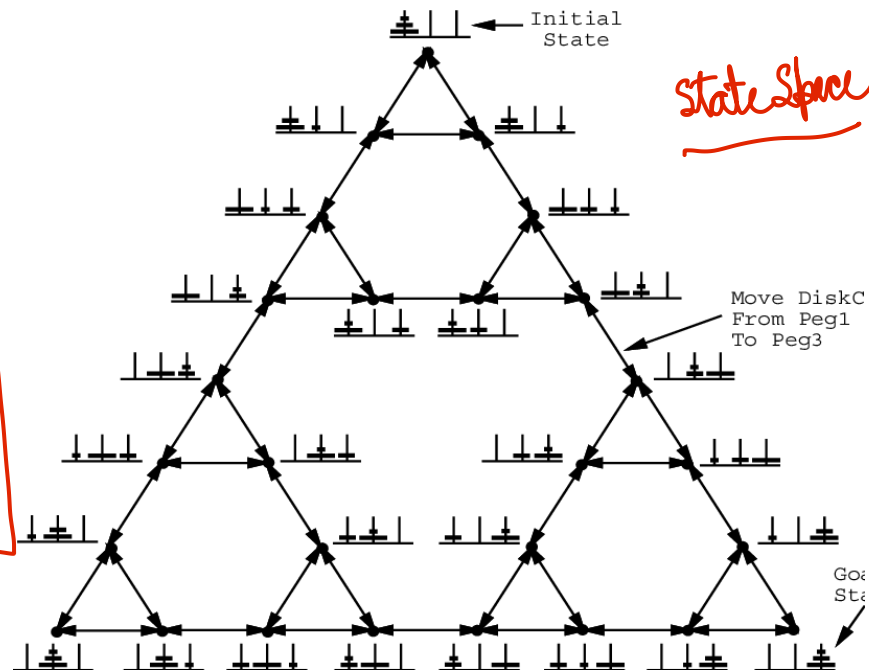
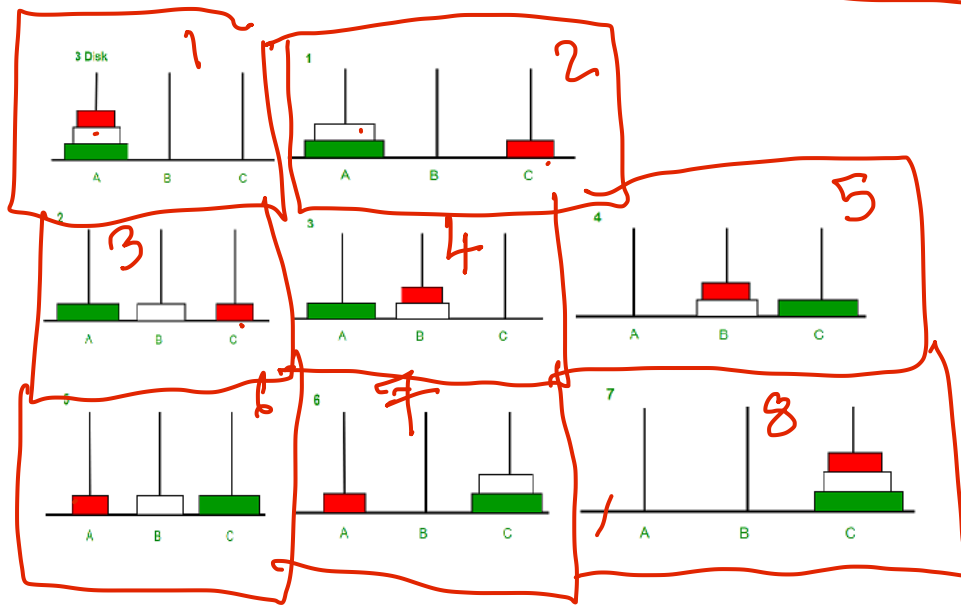
STATE SPACES



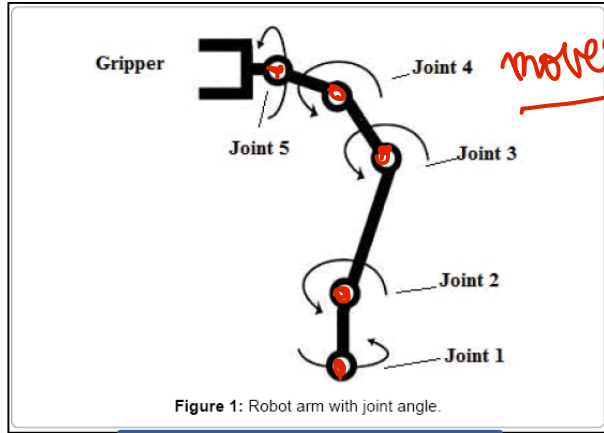
Find out the size of the state space



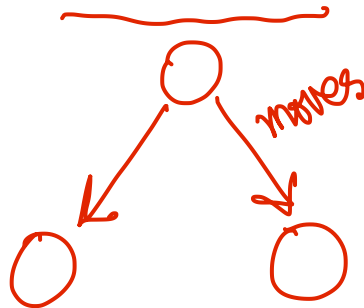
3 DISK, 3 PEG TOWER of HANOI STATE SPACE



STATE SPACES



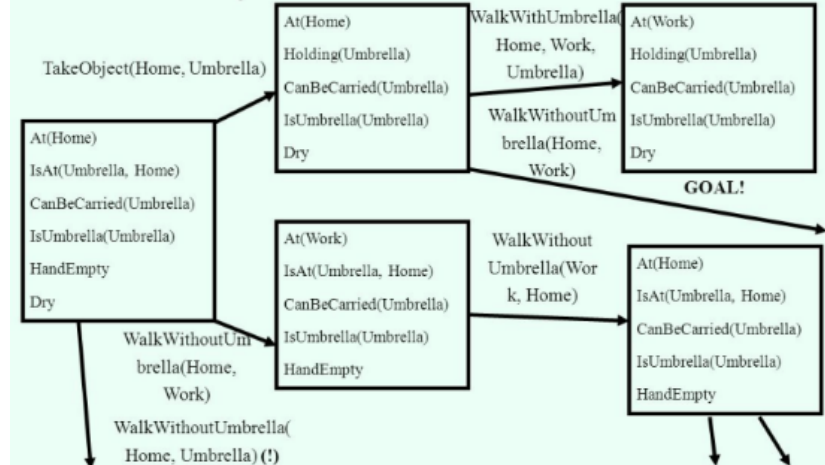
Manipulator Arm



Forward state-space search

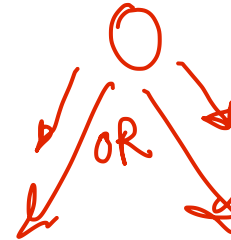
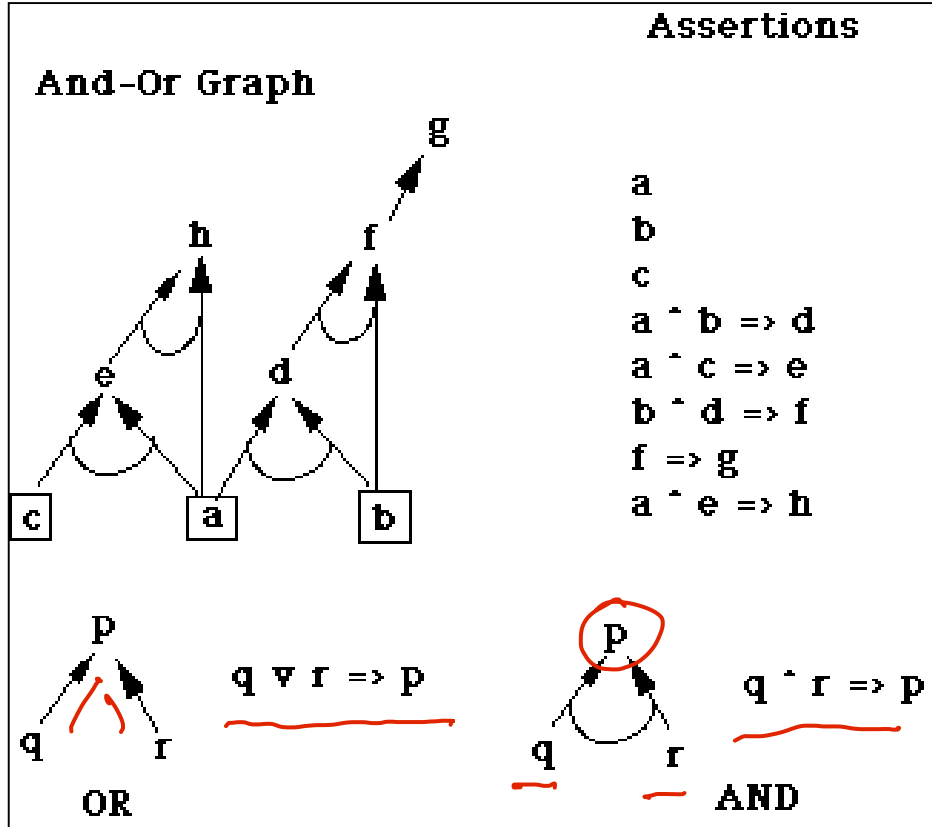
(progression planning)

- Successors: all states that can be reached with an action whose preconditions are satisfied in current state

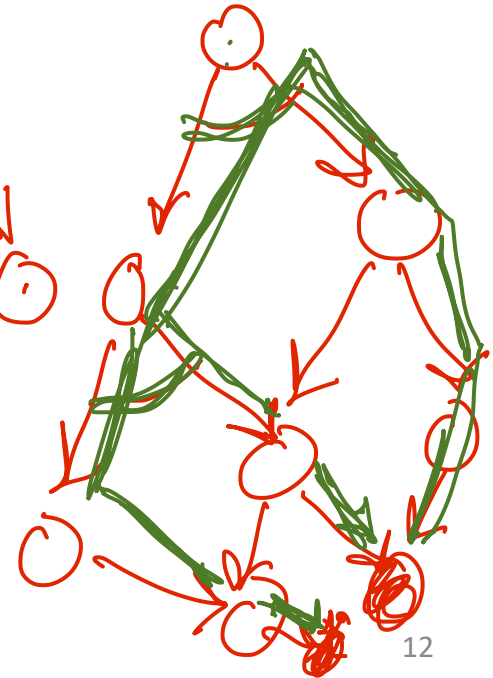
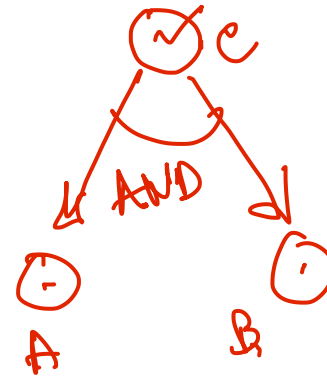


Planning

AND / OR STATE SPACES



Compose a solution from its parts

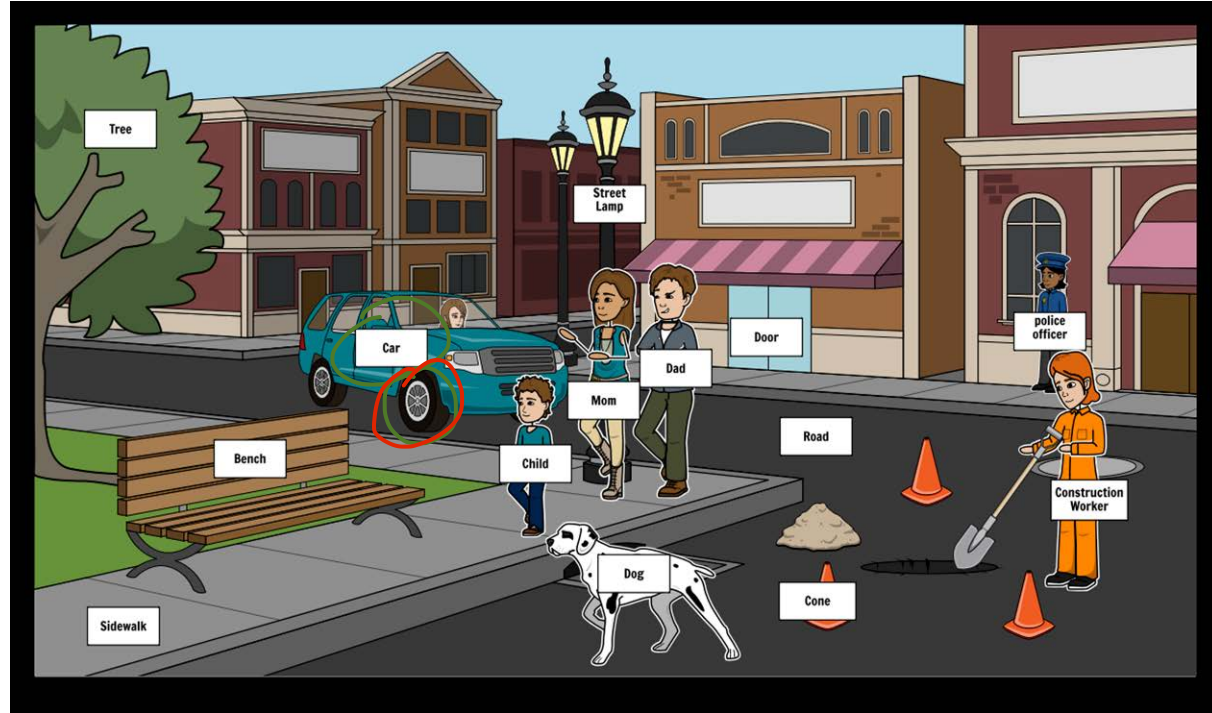


CONSISTENT LABELLING BY CONSTRAINT SATISFACTION

$$\begin{array}{r} \text{B O B} \\ \times \text{B O B} \\ \hline \text{M E O Y} \\ \text{M I L O} \\ \hline \text{M E O Y} \\ \hline \text{M A R L E Y} \end{array}$$

Cryptarithmic

unique digit from
(0 to 9)



Scene Analysis

CONSISTENT LABELLING BY CONSTRAINT SATISFACTION

Crossword

1	L	A	3	E	R	
			A			
	4	L	I	5	N	E
6			7	L	E	E
8			S			

Instructions

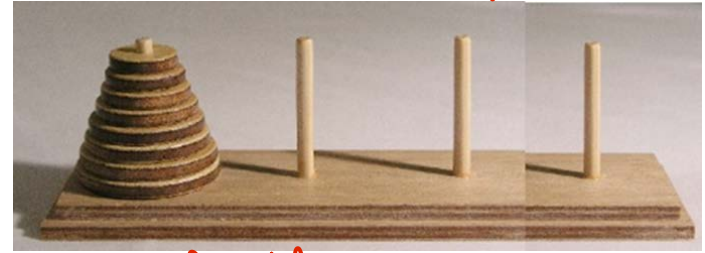
- fill in words from the list

List of Words

• All	• Laser ✓
• Ale	• Lee ✓
• Eel	• Line ✓
• Hike	• Sails ✓
• Hoses	• Sheet
• Keel	• Steer
• Knot	• Tie

STATES, SPACES, SOLUTIONS, SEARCH

- **States**
 - Full / Perfect Information and Partial Information States
- **State Transformation Rules**
 - Deterministic Outcomes
 - Non-Deterministic / Probabilistic Outcomes
- **State Spaces As Generalized Games**
 - Single Player: OR Graphs
 - Multi-Player: And / Or, Adversarial, Probabilistic Graphs
- **Solutions**
 - Paths
 - Sub-graphs
 - Expected Outcomes
- Costs
- Sizes
- Domain Knowledge
- Algorithms for Heuristic Search



Single player

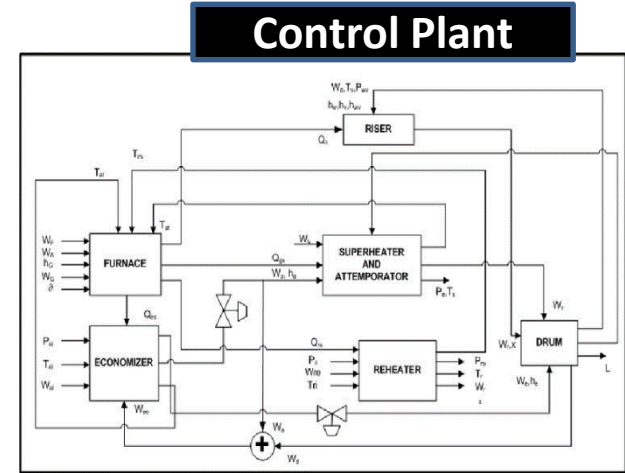


2 player

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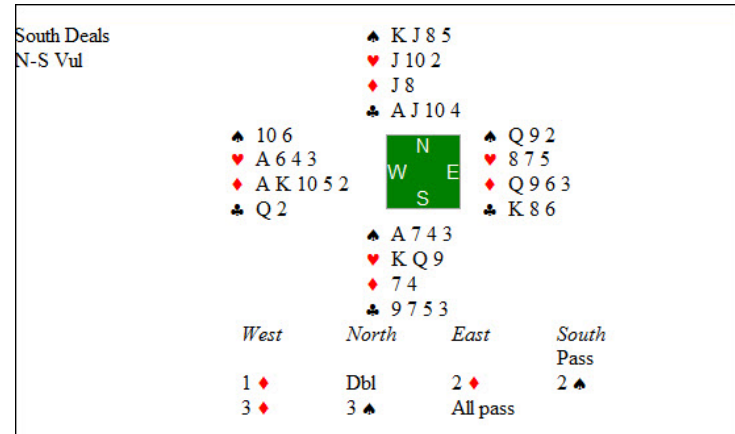
one variable



All the variables are NOT observable nor are they controllable

STATES, SPACES, SOLUTIONS, SEARCH

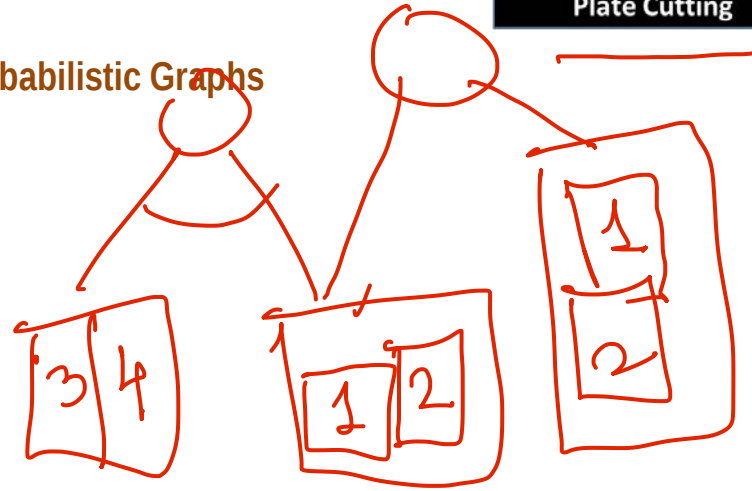
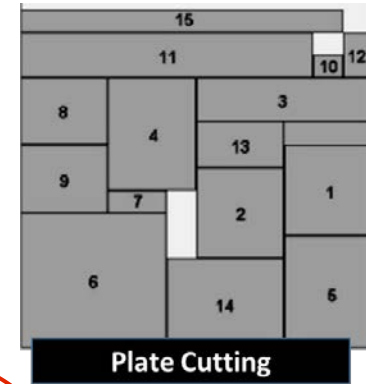
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multi-party games
imperfect / incomplete information

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Thank you