SEARCH METHODS IN AI

AUTOMATED PROBLEM SOLVING

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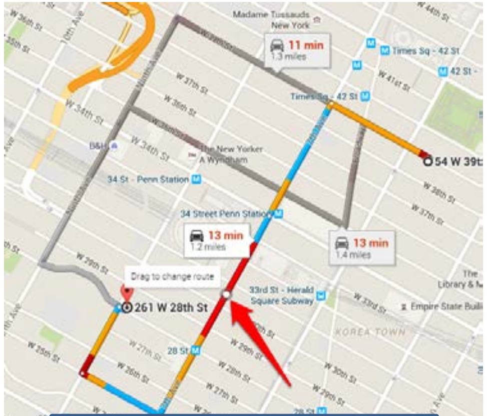
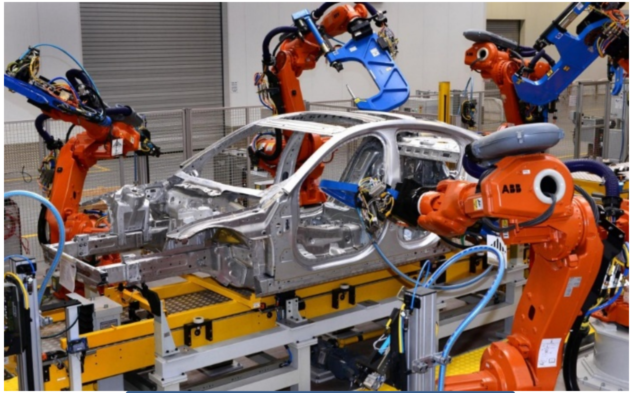
Indian Institute of Technology Kharagpur

COMPLEX PROBLEMS & SOLUTIONS



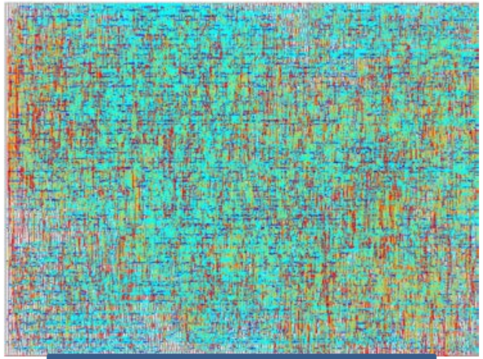
Path Finding

Chess Playing

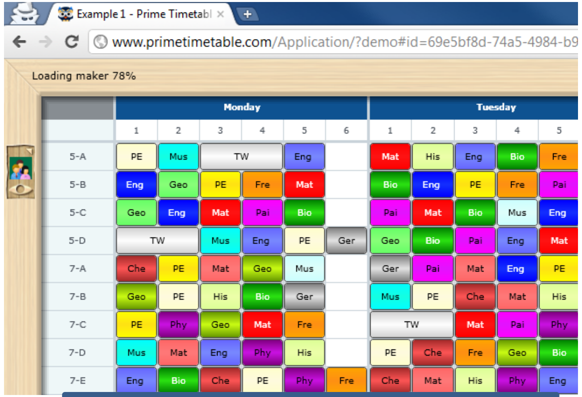


Robot Assembly

COMPLEX PROBLEMS & SOLUTIONS



VLSI Chip Design



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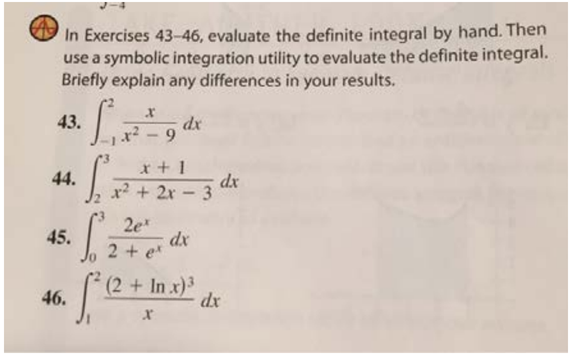
Loading maker 78%

	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	Pai
5-C	Geo	Eng	Mat	Pai	Bio		Pai	Mat	Bio	Mus	Eng
5-D	TW		Mus	Eng	PE	Ger	Geo	Bio	Pai	Eng	Mat
7-A	Che	PE	Mat	Geo	Mus		Ger	Pai	Mat	Eng	PE
7-B	Geo	PE	His	Bio	Ger		Mus	PE	Che	Mat	His
7-C	PE	Phy	Geo	Mat	Fre		TW		Mat	Pai	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



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

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

- Configuration or State
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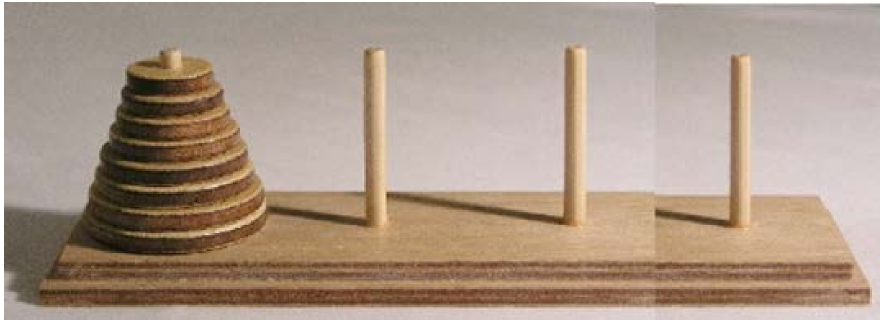

TWO JUG PROBLEM

- 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: <J1, J2>
- Rules:
  - Fill (J1): <J1, J2> to <3,J2>
  - Fill (J2): <J1, J2> to <J1, 5>
  - Empty (J1), Empty (J2): Similarly defined
  - Pour (J1, J2): <J1, J2> to <X,Y>, where
    - **X = 0 and Y = J1 + J2 if J1+J2 ≤ 5,**
    - Y = 5 and X = (J1+ J2) – 5, if J1+J2 > 5
  - Pour (J2, J2): Similarly defined
- Start: <0,0>, Goal: <1,0>
- Part of State Space Shown on the right

(Not all Links shown here)

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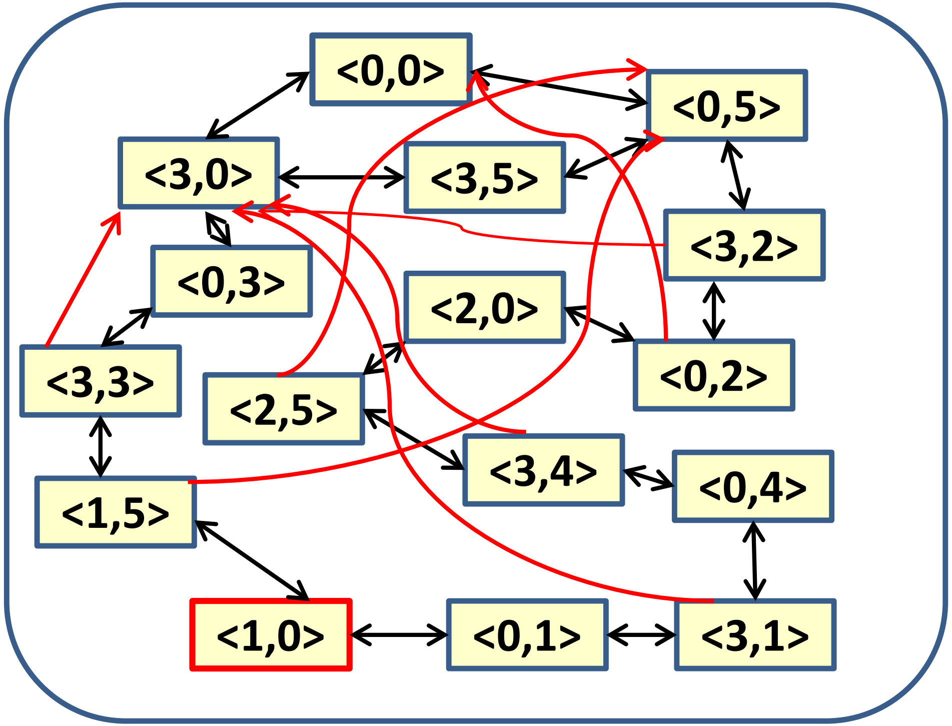
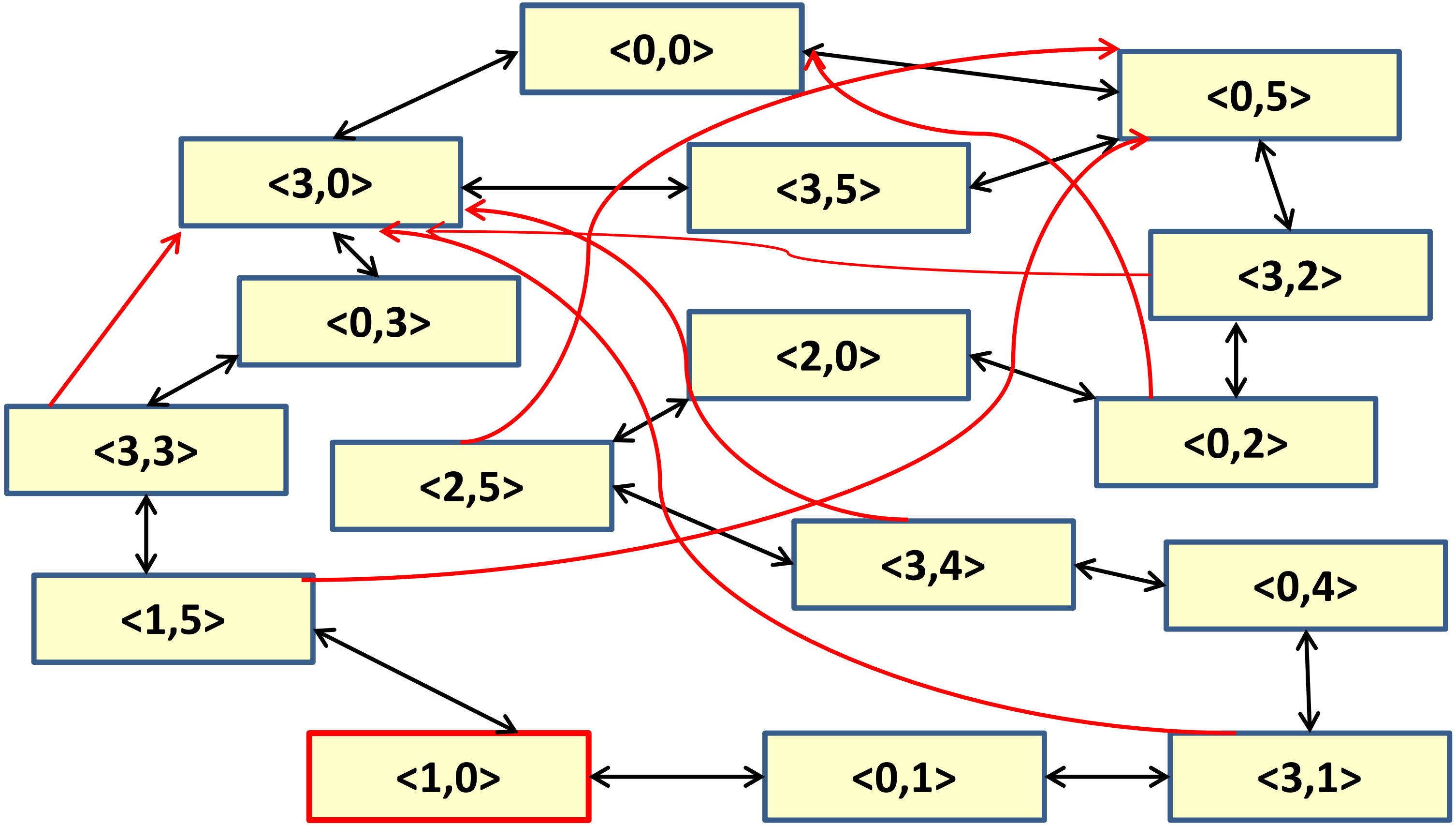
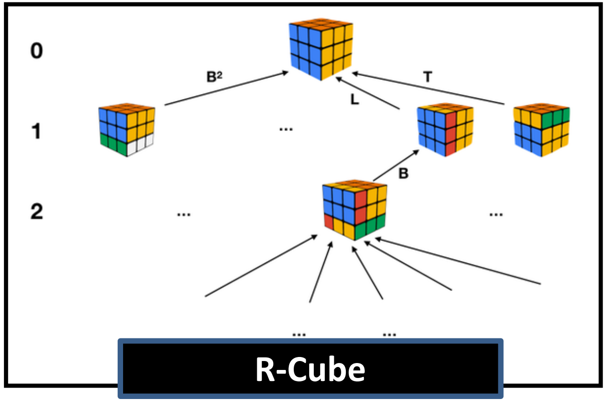


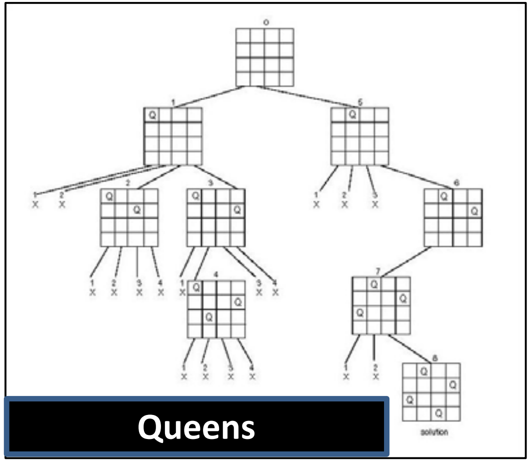
PART OF STATE SPACE



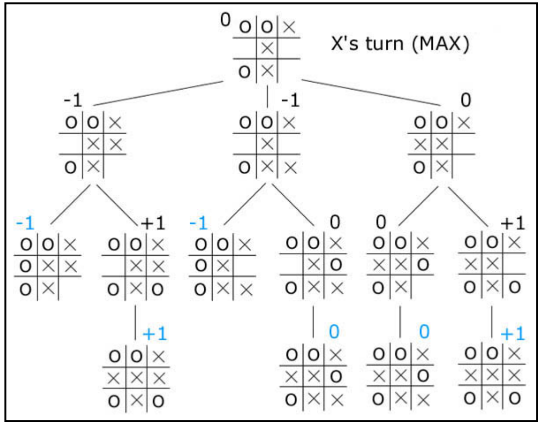
STATE SPACES



R-Cube

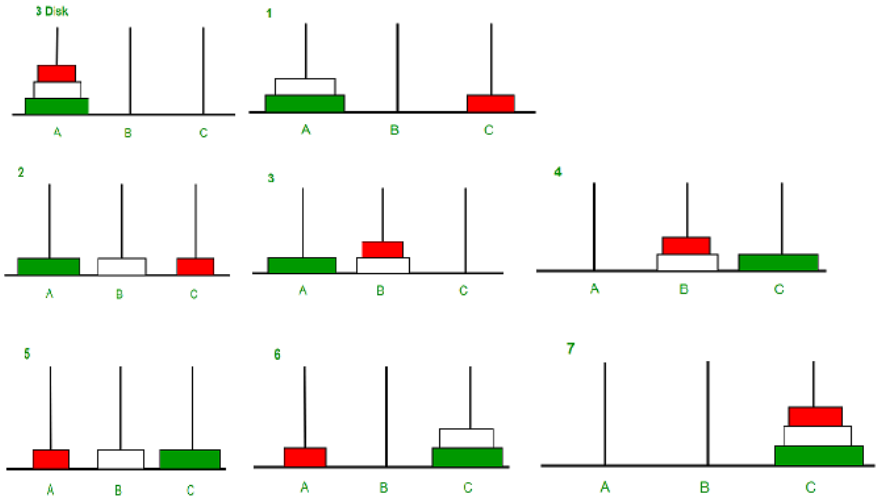


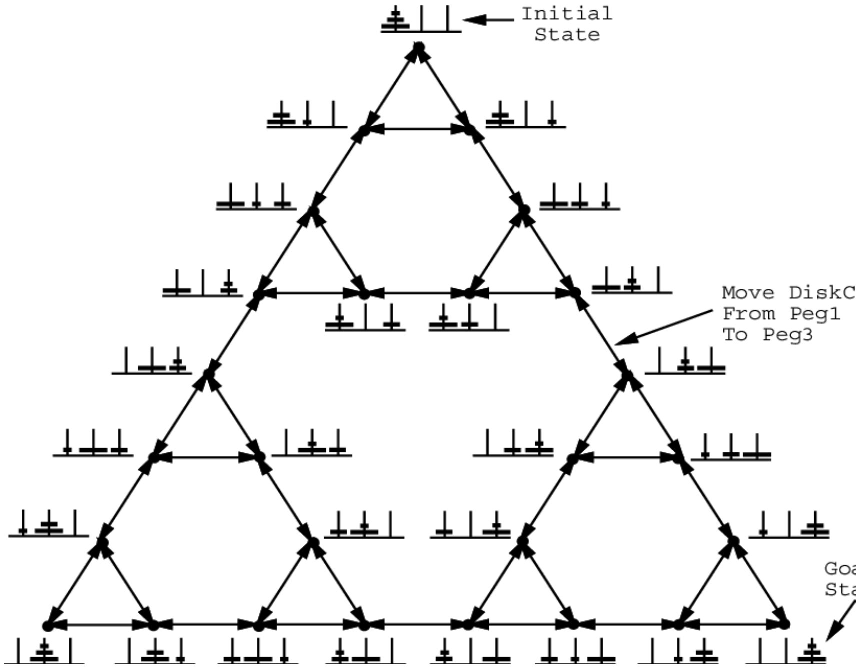
Queens



Game

3 DISK, 3 PEG TOWER of HANOI STATE SPACE





STATE SPACES

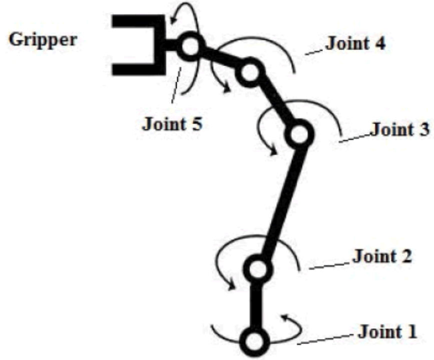
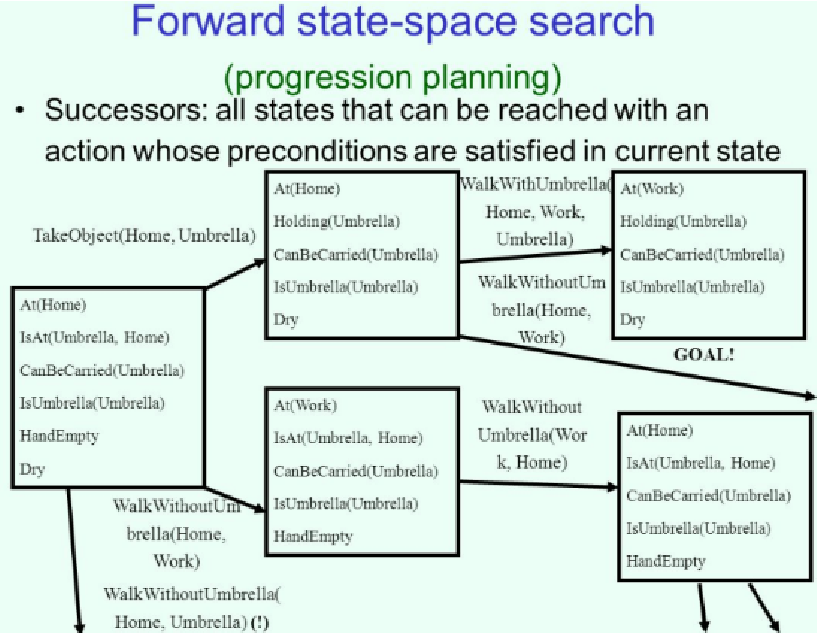


Figure 1: Robot arm with joint angle.

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

At(Home)
IsAt(Umbrella, Home)
CanBeCarried(Umbrella)
IsUmbrella(Umbrella)
HandEmpty
Dry

TakeObject(Home, Umbrella)

At(Home)
Holding(Umbrella)
CanBeCarried(Umbrella)
IsUmbrella(Umbrella)
Dry

WalkWithUmbrella(Home, Work, Umbrella)

At(Work)
Holding(Umbrella)
CanBeCarried(Umbrella)
IsUmbrella(Umbrella)
Dry

GOAL!

WalkWithoutUmbrella(Home, Work)

WalkWithoutUmbrella(Home, Work)

At(Work)
IsAt(Umbrella, Home)
CanBeCarried(Umbrella)
IsUmbrella(Umbrella)
HandEmpty

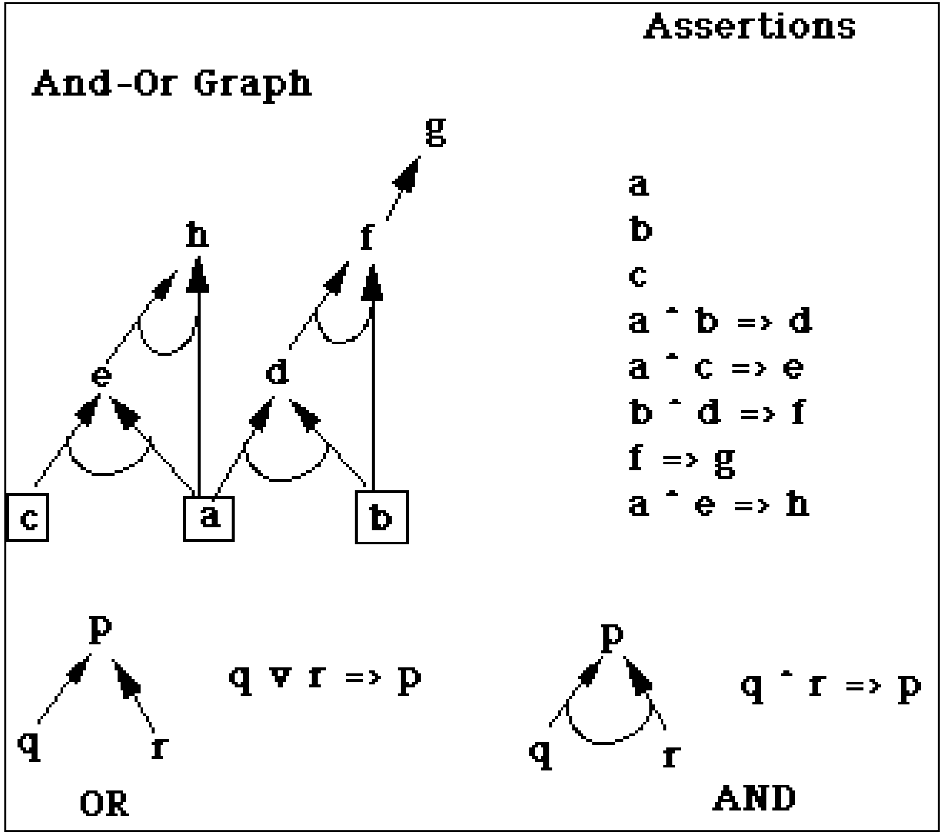
WalkWithoutUmbrella(Work, Home)

At(Home)
IsAt(Umbrella, Home)
CanBeCarried(Umbrella)
IsUmbrella(Umbrella)
HandEmpty

WalkWithoutUmbrella(Home, Umbrella) (!)

Planning

AND / OR STATE SPACES



Assertions

a
b
c
a ^ b => d
a ^ c => e
b ^ d => f
f => g
a ^ e => h

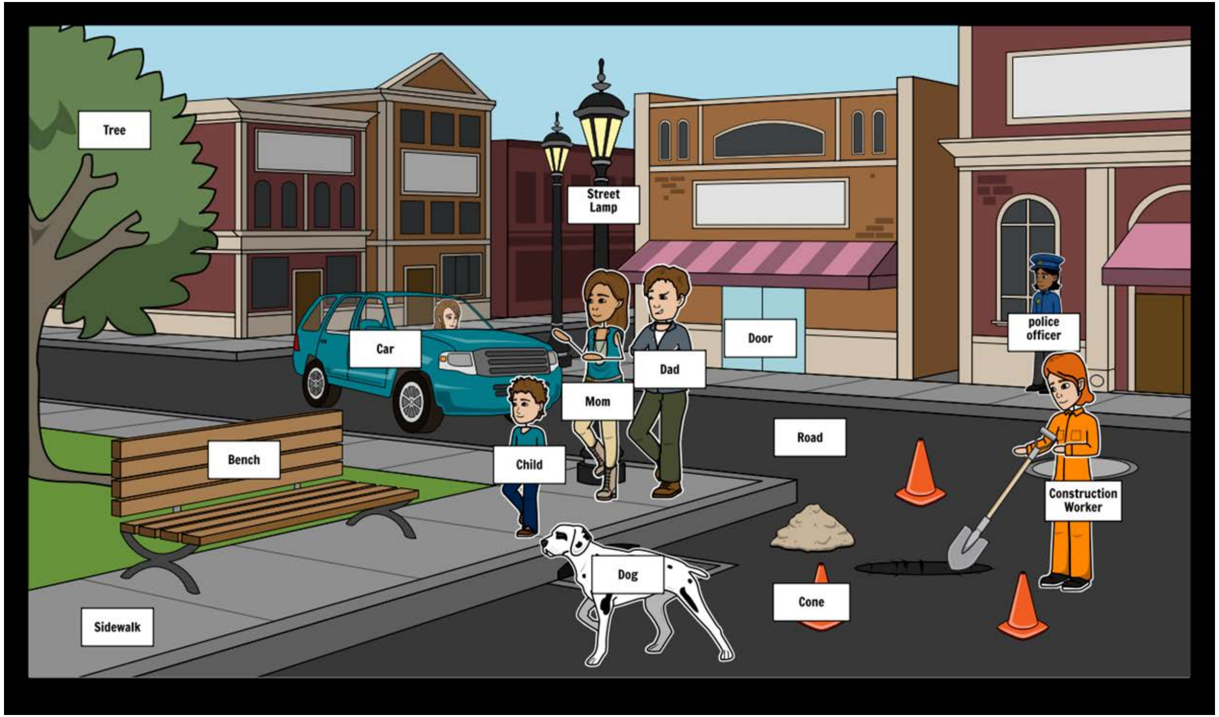
q v r => p

q ^ r => p

CONSISTENT LABELLING BY CONSTRAINT SATISFACTION

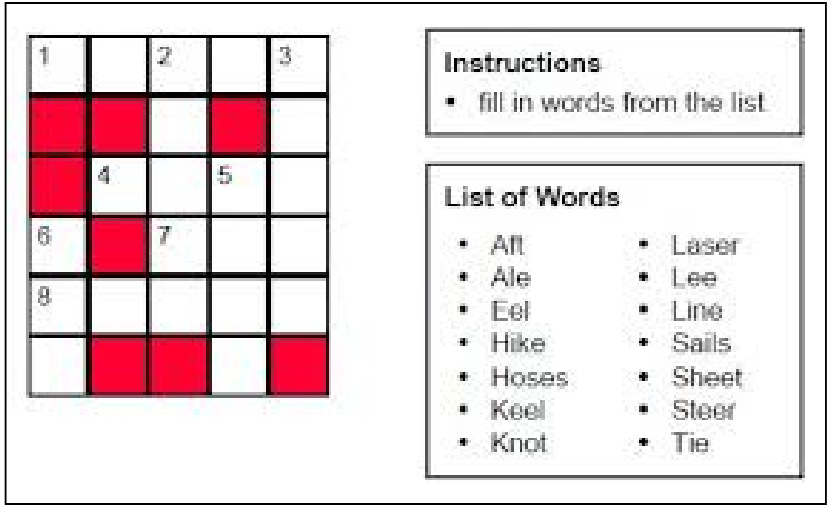
```
      B O B
    × B O B
    -------
    M E O Y
  M I L O
M E O Y
-----------
M A R L E Y
```

Cryptarithmetic



Scene Analysis

CONSISTENT LABELLING BY CONSTRAINT SATISFACTION



1		2		3
🟥	🟥		🟥	
🟥	4		5	
6	🟥	7		
8				
	🟥	🟥		🟥

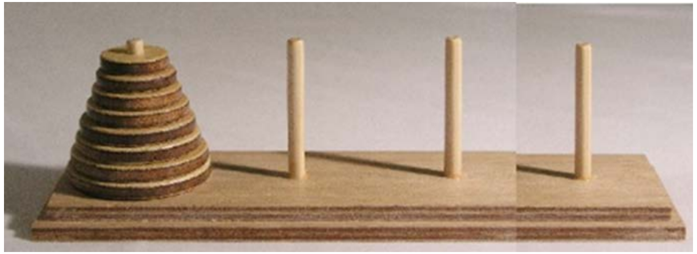
Instructions

- fill in words from the list

List of Words

- Aft
- Ale
- Eel
- Hike
- Hoses
- Keel
- Knot
- Laser
- Lee
- Line
- Sails
- Sheet
- Steer
- 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

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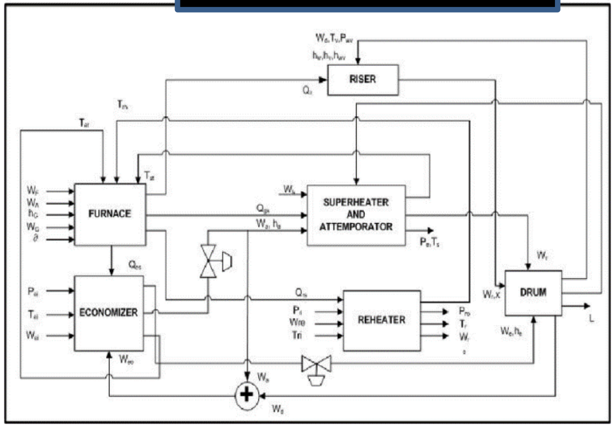
Control Plant



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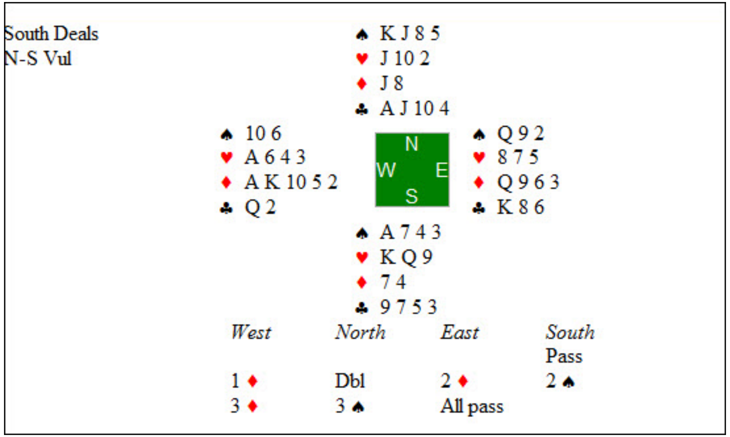

South Deals
N-S Vul

♠ K J 8 5
♥ J 10 2
♦ J 8
♣ A J 10 4

♠ 10 6
♥ A 6 4 3
♦ A K 10 5 2
♣ Q 2

♠ Q 9 2
♥ 8 7 5
♦ Q 9 6 3
♣ K 8 6

♠ A 7 4 3
♥ K Q 9
♦ 7 4
♣ 9 7 5 3

West	*North*	*East*	*South*
			Pass
1 ♦	Dbl	2 ♦	2 ♠
3 ♦	3 ♠	All pass	

STATES, SPACES, SOLUTIONS, SEARCH

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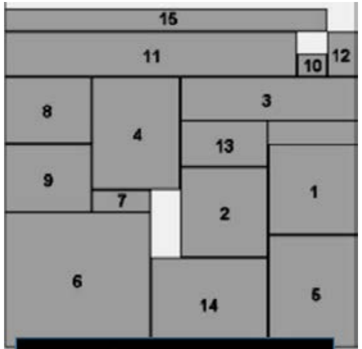

Plate Cutting

Thank you