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→ <u>Various Levels of Knowledge Base Agents</u>
① Knowledge level
② Logical level
③ Implementation level

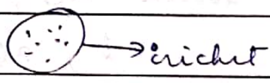
→ <u>Approaches to design KBA</u>
① Declarative approach → store knowledge with eng type statement (non ambiguity)
② Procedural approach → programming, mathematical notation

→ First Order Predicate:
↳ used for knowledge representation.
→ <u>Symbols used</u>

$\neg$	not
$\wedge$	and
$\vee$	or
$\rightarrow$	implies
$\leftrightarrow$	if and only if (iff)

→ Quantifiers
i) Universal quantifiers (for all, everything, for each)
$\forall$ →
ii) Existential Quantifiers (for some, atleast one)
$\exists$ $\wedge$

eg. <u>All boys like cricket</u>
$\forall x : boy(x) \rightarrow \underbrace{like(x, cricket)}_{predicate}$



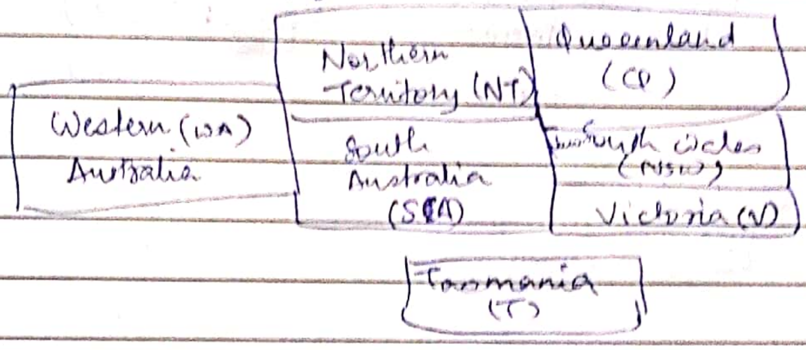
eg. Some boys like cricket
$\exists x : boys(x) \wedge like(x, cricket)$

Constraint Satisfaction Problem (CSP)

1) Forward Checking

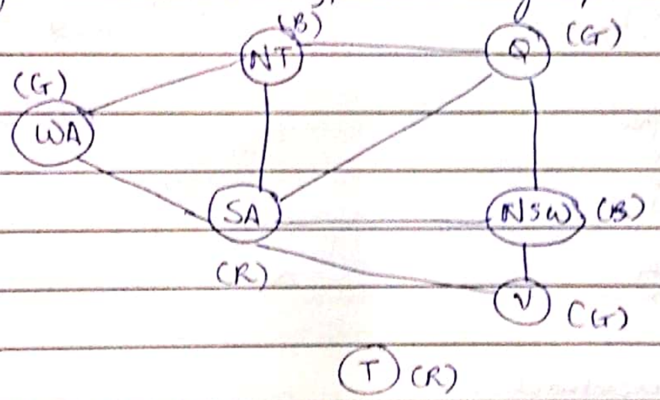
- Keep track of remaining legal values for unassigned variables
- Terminate search when any variable has no legal values
- Constraint Propogation

eg:



eg. Using forward checking, solve graph coloring problem

Sol^n



Forward checking

D = {red, green, blue}

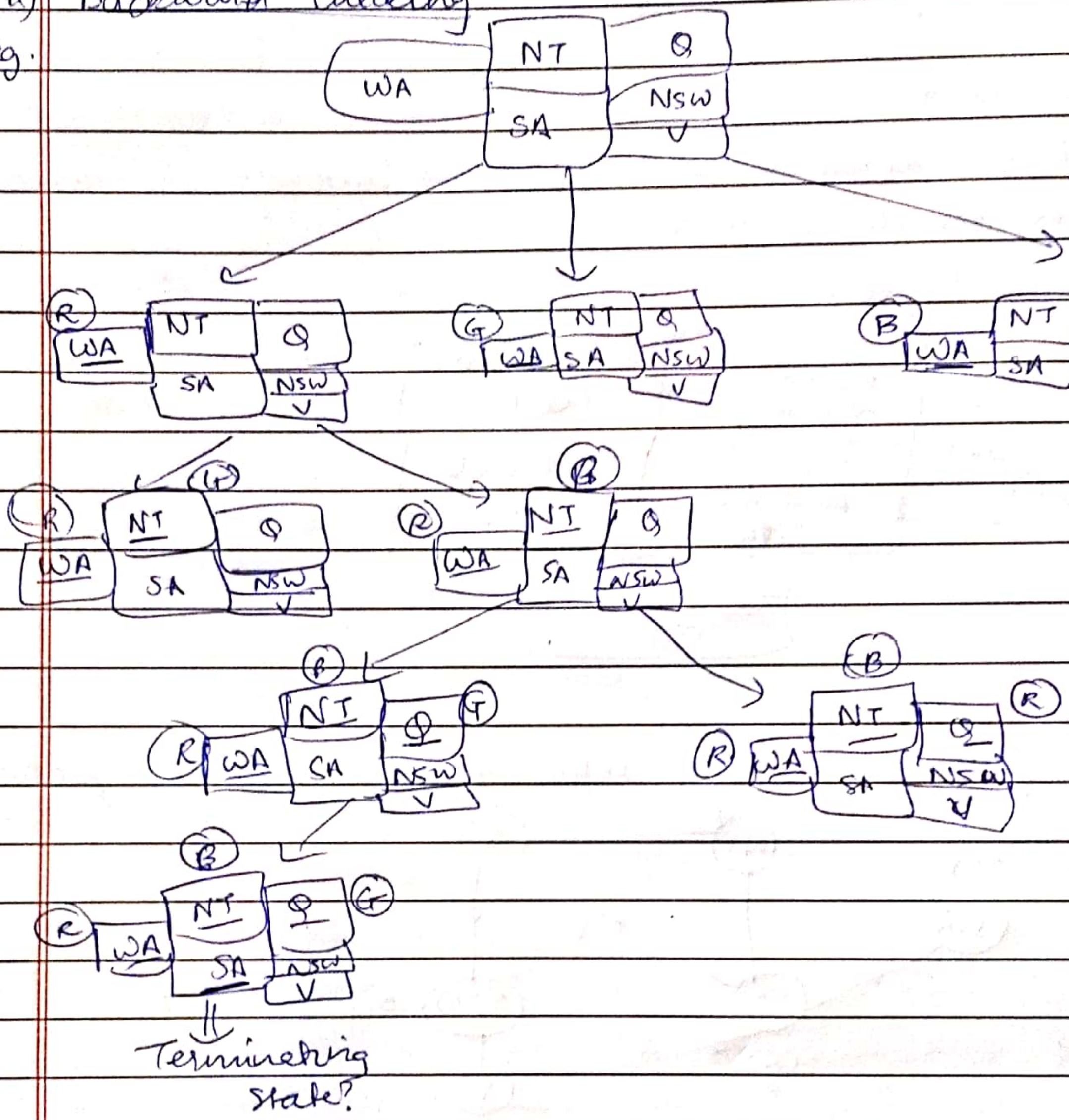
V = {WA, NT, SA, Q, NSW, V, T}

C = {Adjacent nodes/regions must have different colours}

WA	R×	G	B×
NT	R×	G×	B
SA	R	G×	B×
Q	R×	G	B×
NSW	R×	G×	B
V	R×	G	B×
T	R	G×	B×

2) Backward Checking

eg.



Improving Backtracking

→ which variable should be assigned next

→ The order in which values should be tried.

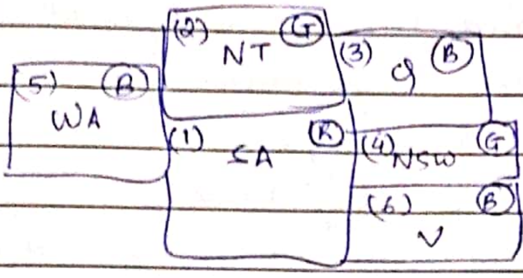
→ Can detect failures early

→ Will solve backtracking using Heuristic

→ Most Constraint Variable (MCV) → (Minimum Remaining value)

→ Least Constraint Variable (LCV)

→ Most constraint Variable

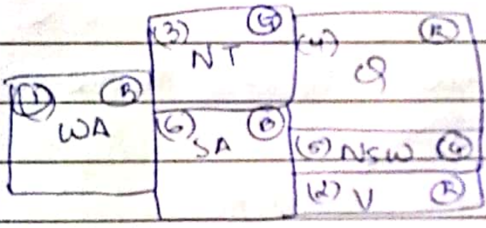


Note: Select first a node with more no. of neighbours & proceed accordingly (MORE → LESS)

SA — 1 — R
NT — 2 — G
Q — 3 — B
NSW — 4 — G
WA — 5 — B
V — 6 — B

} or ulta?

→ Least Constraint value



Note: select first a node with few no. of neighbours & proceed accordingly (LESS → MORE)

WA — 1 — R
V — 2 — R
NT — 3 — G
Q — 4 — R
NSW — 5 — G
SA — 6 — B

Adversal Search MinMax:

1) For the foll code state find the optimal (move) node for the first player using minmax algorithm

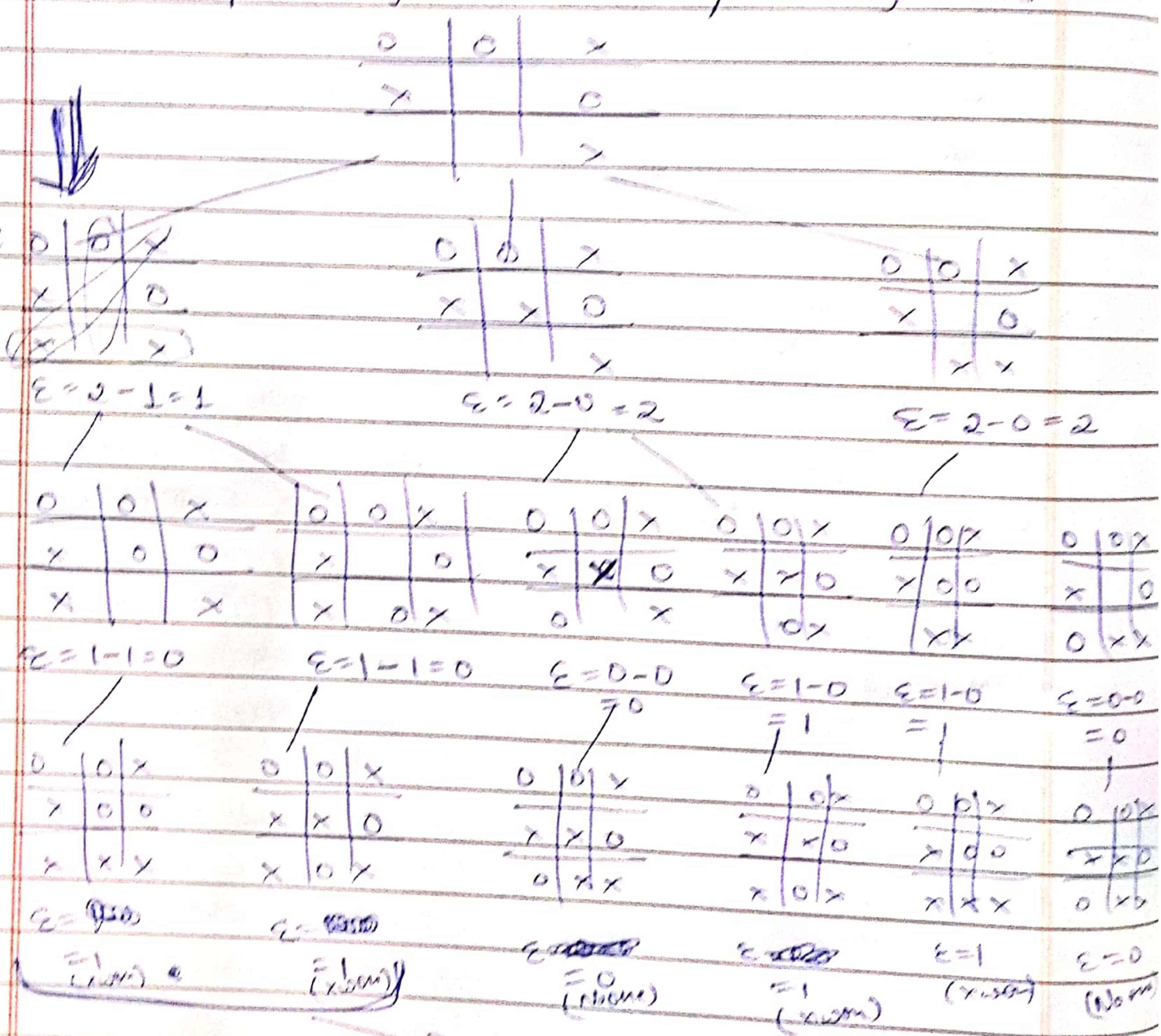
O	O	X
X		O
		X

X - player

O - opponent

heuristic function is denoted by

E = X' possibility to win - O possibility to win



∴ Optimal move:

O	O	X
X		O
X		X

2) Find the worst move for player x for minmax algo

O		X
X		
X	O	O

3) For the foll state board find the optimal (move?) node for player x using min max algo.

X		O
	O	X
	X	O

2)

O		X
X		
X	O	O

X-turn:

O	X	X
X		
X	O	O

$\varepsilon = 2-1 = 1$

O		X
X	X	
X	O	O

$\varepsilon = 1$
(x won)

O		X
X		X
X	O	O

$\varepsilon = 2-2 = 0$

O-turn:

O	X	X
X	O	
X	O	O

$\varepsilon = 0-1 = -1$
(O won)

O	X	X
X		O
X	O	O

$\varepsilon = 1-1 = 0$

O	O	X
X		X
X	O	O

$\varepsilon = 2-2 = 0$

O		X
X	O	X
X	O	O

$X = 0-1 = -1$
(O won)

X-turn:

O	X	X
X	X	O
X	O	O

$\varepsilon = 1-0 = 1$
(x won)

O	O	X
X	X	X
X	O	O

(X won)

∴ Worst move is

O	X	X
X		
X	O	O

or

O		X
X		X
X	O	O

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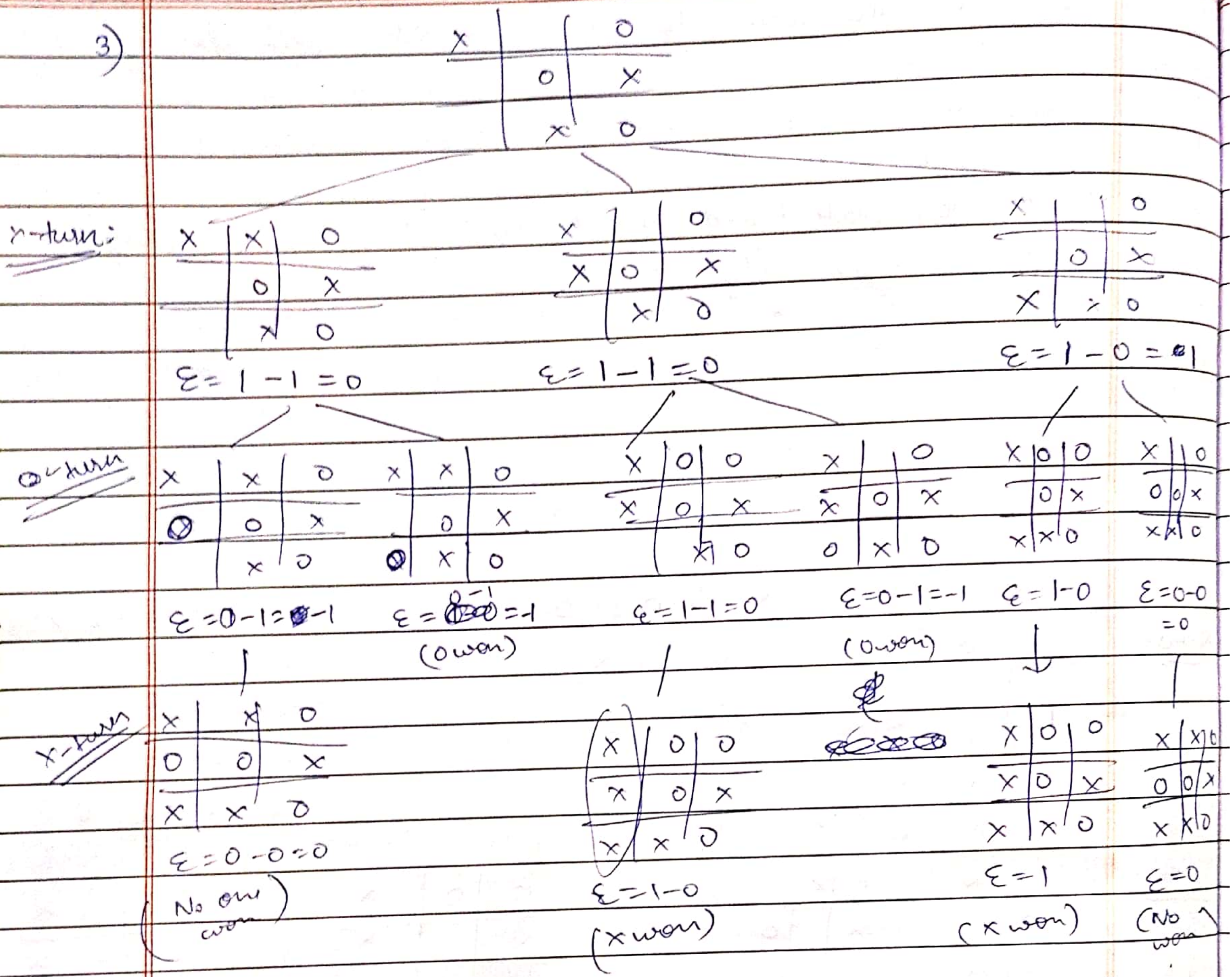
3)



∴ Optimal move

X		O
	O	X
X	X	O

→ First Order Predicate logic :

$\underbrace{\text{All students}}_{\text{subject}}$ $\underbrace{\text{like}}_{\text{predicate}}$ $\underbrace{\text{football}}_{\text{subject}}$ → x likes football.

eg. All students like football

$\forall x : student(x) \rightarrow like(x, football)$

$\forall x (\quad)$

eg. Some students like football

$\exists x : student(x) \wedge like(x, football)$

eg. All students are happy

$\forall x (student(x) \rightarrow happy(x))$

$arehappy(x))$

eg. some students are happy

$\exists x (student(x) \wedge arehappy(x))$

eg. Every Rational no. is a real no.

$\forall x (rational(x) \rightarrow real(x))$

eg. Some real no. are rational nos

$\exists x (real(x) \wedge rational(x))$

eg. Not(every real no is a rational no.)

$\neg \forall x (real(x) \rightarrow rational(x))$

eg. Every student in this class has visited Africa or America

$\forall x (student(x) \rightarrow visited(x, Africa) \vee visited(x, America))$

eg. Some prime nos are even nos.

$\exists x (prime(x) \wedge even(x))$

eg.

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Represent the foll sentence in the first order logic

1) Not all students take both maths & biology.
=) $\sim \{ \forall x \,(student(x) \rightarrow take(x, maths) \land take(x, biology))$

? 2) Only one student failed in maths & biology
o =) $\exists x\,(student(x) \land failed(x, maths) \lor failed(x, biology))$
?

? 3) Only one student failed in both maths & biology.
o =) $\exists x\,(student(x) \land failed(x, maths) \land failed(x, biology))$.

? 4) Every student who took Robotics passes the exam.
o =) $\forall x\,(student(x) \rightarrow took(x, Robotics) \land passes(x, exam)$

5) Every person who buys a policy is smart.
=) $\forall x\,(person(x) \rightarrow buys(x, policy) \land issmart(x))$

6) There is an agent who sells policies only to those people who are not insured.
? =) $\exists x\,(agent(x) \land sells(x, policies) \land notinsured(people?))$
o $\exists(x,y)\,(agent(x) \land people(y) \land sells(x, policies \land insured(y, not))$
7) No person buys expensive policies.
=) $\sim \{ \forall x\,(person(x) \rightarrow buys(x, expensivepolicies))$

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Unification :

→ Unification is a process of making two different logical atomic expressions identical by finding a substitution.
→ Unification depends on substitution process.
→ It takes two literals as input and makes them identical using substitution.
→ Let L_1 and L_2 be two atomic sentences and σ be the unifier such that

$L_1\sigma = L_2\sigma$ that it can be expressed as

UNIFY(L_1, L_2)

eg. UNIFY(king(x), king(JOHN))
⟹ L_1 = king(x) , L_2 = king(JOHN)
$\Theta = \{x \mid John\}$

eg. UNIFY(knows(John, x) , knows (John, Jane))
⟹ L_1 = knows(John, x) , L_2 = knows(John, Jane)
$\Theta = \{x \mid Jane\}$

eg. UNIFY(knows (John, x) , knows (y, mother(y))
⟹ L_1 = knows(John, x) , L_2 = knows (y, mother(y))

$\Theta = \{ y \mid John, \; x \mid mother(John) \}$

eg. p(x, f(y)) p(a, f(g(z))
$L_1 = p(x, f(y))$, $L_2 = p(a, f(g(z))$

$\Theta = \{ x \mid a , y \mid g(z) \}$

→ The unify algorithm is used for unification which takes 2 atomic sentences and returns a unifier for those sentences.

→ Unification is a key component for all first order inference algorithm

→ It returns 'fail' if the expressions do not math with each other. The substitution variables are called most general unifier (mgu).

→ Condition for unification:
- ↳ Predicate symbol must be same
- ↳ Expression with different predicate symbols can never be unified.
- ↳ The no. of arguments in both the expression must be identical.

Algorithm:

1) If L_1 and L_2 is a variable or constant then
   - (a) If L_1 and L_2 are identical then return NULL
   - (b) Else if L_1 is a variable then, if L_1 occurs in L_2 then return ~~fail~~ FAIL else return $\{(L_1 / L_2)\}$
   - (c) Else if L_2 is a variable then, if L_2 occurs in L_1 then return FAIL else return $\{(L_2 / L_1)\}$
   - (d) Else return FAIL
2) If the initial predicate symbol in L_1 and L_2 are not identical then return FAIL.
3) If L_1 and L_2 have different number of arguments then return FAIL
4) SET SUBS to NIL
5) loop
6) Return SUBS.

Planning & Probabilistic Reasoning

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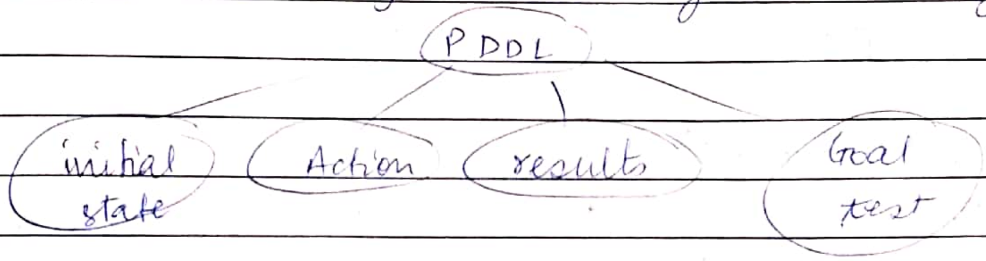
Planning

Devising a plan of action to achieve one's goal is called planning.

→ Classical planning approach.

PDDL (Planning Domain Definition Language)



Initial State

Each state is represented as a conjunction of fluent that are ground functionless atoms.

eg. At (Truck1, melbourne) ∧ At (Truck2, sydney)

atoms

Action:

The schema consists of action name, a list of variables used in the schema a precondition and an effect

eg. Action [fly (P₁, SFO, JFK)]

Precondition: At (P₁, SFO) ∧ Plane (P₁) ∧ Airport (SFO) ∧ Airport (JFK)

Effect: ¬ At (P₁, SFO) ∧ At (P₁, JFK)

Problems:

Air Cargo Transport (ACT)

The Air cargo Transport problem involves loading and unloading cargo & flying it from place to place.

The problem can be defined with 3 action.

(a) Load

(b) Unload

(c) Fly.

eg. SFO C_1 P_1 — JFK C_2 P_2

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Solⁿ: Initial state

Initial [At(C_1, SFO) ∧ At(C_2, JFK) ∧ At(P_1, SFO) ∧ At(P_2, JFK) ∧ Cargo(C_1) ∧ Cargo(C_2) ∧ Plane(P_1) ∧ Plane(P_2)]

Goal state

Goal [At(C_1, JFK) ∧ At(C_2, SFO)].

① Action (load (c, p, a))

Pre-condition: At (c, a) ∧ At (p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)

Effect: ¬ At (c, a) ∧ In (c, p)

(Inside / IN)

② Action (unload (c, p, a))

Pre-condition: In (c, p) ∧ At (p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)

Effect: At (c, a) ∧ ¬ In (c, p)

③ Action (fly (p, from, to))

Pre-condition: At (p, from) ∧ Plane (p) ∧ Airport (from) ∧ Airport (to)

Effect: ¬ At (p, from) ∧ At (p, to)

The following plan is a solution to the problem:

→ load (c_1, p_1, SFO), fly(p_1, SFO, JFK), unload (c_1, p_1, JFK)

→ load (c_2, p_2, JFK), fly (p_2, JFK, SFO), unload (c_2, p_2, SFO)

The Block World :

→ One of the most famous planning domain is known as "The Block World".

→ It consist of set of cube shaped blocks sitting on a table.

→ Blocks can be stacked, but only one at a time.

→ A Robot arm can pick up a block & move it to another position, either on a 'table' or 'on top of another block.

→ The arm can pick-up only 1 block at a time

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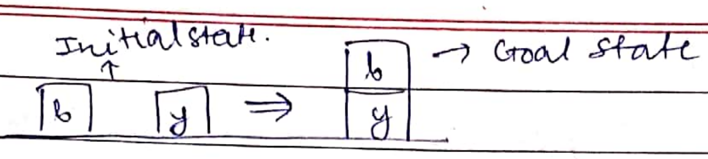
eg1:



*) Action (move (b, x, y))

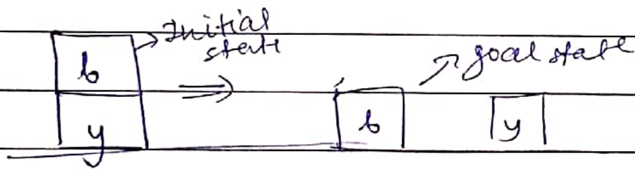
Pre-condition: On (b, x) ∧ clear(b) ∧ clear(y) ∧ Block(B) ∧ Block(y)
(b ≠ x) ∧ (b ≠ y) ∧ (x ≠ y)

Effect: on (b, y) ∧ clear (x) ∧ ¬ On (b, x) ∧ ¬ Clear (y)

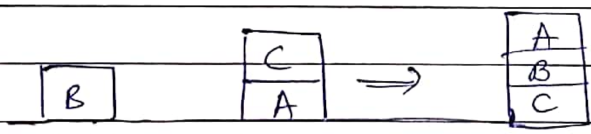
*) Action (movetotable (b, x))

Pre-condit^n: On (b, x) ∧ clear(b) ∧ Block(b) ∧ (b ≠ x)

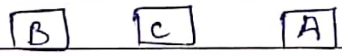
Effect: On (b, table) ∧ clear (x) ∧ ¬ On (b, x)



eg2:

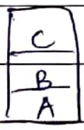


Sol^n ①



②

③



Initial [On (A, table) ∧ On (B, table) ∧ On (C, A) ∧ Block (A),
Block (B) ∧ Block (C) ∧ clear (B) ∧ clear (C)]

Goal [On (A, B) ∧ On (B, C)]

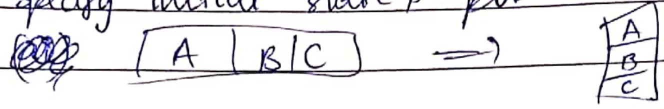
Moves Reqd :

move to table (C, A)

move (B, table, C)

move (A, table, C)

*) Set up the formulation to solve the foll block world problems. Specify initial state & possible action to achieve the goal state.

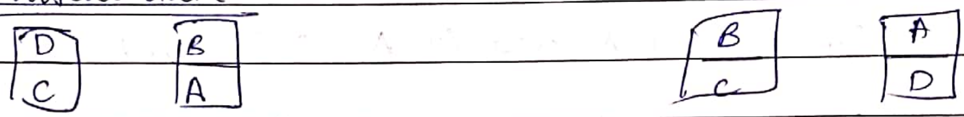


move (B, table, C)

move (A, table, B)

eg 3 Consider the foll. Block World problem, where it has states as follows:

Initial State Goal state



Quest: → Prob
Axiom
Utility & Max ~~utility~~
expected utility?

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Probability:

→ It can be defnd as a chance that an uncertain event, will occur

→ It is a numerical measure of the likelihood that an event will occur.

→ The value of probability always remains between 0 and 1, that represents the ideal uncertainty.

→ It can be denoted as "$0 \leq P(A) \leq 1$ where $P(A)$ is the probability of event.

→ $P(A) = 0$, indicates total uncertainty.

→ $P(A) = 1$, indicates total certainty in an event.

Sample space (Ω)

→ Set of all possible outcomes of a random experiment

eg. Dice roll = $\{1, 2, 3, 4, 5, 6\}$

Tossing up a coin = {head, tail}

Event space (F)

→ Subset of element in a sample space.

eg. Dice roll = $\{3, 4\}$

Tossing a coin = $\{T\}$

imp

Axioms of Probability

Let 'S' be the sample space, and let 'Ai', 'Aj' be the event in sample space 'Si'.

Axioms.

1. $P(A) \geq 0$ or $0 \leq P(A) \leq 1$
2. $P(S) = 1$; 100% chance
3. if we take event A & B, and $A \cap B = \phi$ then $P(A \cup B) = P(A) + P(B)$

In general, '$\cap A_i = \phi$', then $\cup P(A_i) = P(A_1) + P(A_2) + \ldots$

why uncertainity arises?
- theoretical ignorance
- practical ignorance

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imp ⇒ Uncertainity and Rational Decisions (Rationality)

eg. Plan1 (A90) → leave 90 min early
Plan 2 (A180) → leave 180 min early
Plan3 (A1440) → leave 24 hrs early

→ 10km ≃ Maybe Plan2.

Utility value
eg. ↳ On Time (reach on time)
↳ legal (take legal route)
↳ safe
↳ comfortable journey

Utility Theory: The utility theory says that every state has a degree of usefulness or utility to an agent and that agent will prefer states with higher utility.

imp Maximum Expected Utility (MEU):
The decision theory combines the agent belief and desire defining the best action as the one that maximizes expected utility.

Unconditional Probability & Conditional Probability:
imp → Unconditional Prob / Prior Probability.
↳ The term refers to the likelihood that an event will take place regardless of whether other events have occured or other condition exists.

eg. Rolling 2 dice s.t. they should add up to 11
$p(\text{Total}=11) = P(5,6), P(6,5)$

eg. u get heads 5 times will its prob change? No H=0.5

eg. 1 dice $P(1) = 1/6$
2 dice $P(1,1) = 1/36$

2 dice $P(\text{total}=11) = P(5,6) + P(6,5)$
$= 1/36 + 1/36$

→ Conditional Probability:

It is known as the possibility of an event or outcome happening based on the existance of a previous events or outcomes.

eg. Rolling 2 dices given that the first is a 5 what is the probability to get 11. ⇒ $P(\text{total}=11 / 5) = P(5,6) = 1/36$

→ conditional Probability is given as

$$P(a/b) = P(a \cap b) / P(b)$$

→ product rule: $p(a \cap b) = p(a/b) * P(b)$

~~eg.~~ $\cancel{P(\text{total}=11/5) = \frac{P(\text{total}=11 \cap 5)}{P(5)} = \frac{1/36}{1/6}}$

Random Variable:

The variable whose value is unknown or a function that assigns value to each of experimental outcomes.

eg) weather → Random in Nature

Weather ← {humid, rainy, snow, sunny}.

eg. "The Probability that the patient has a cavity given that she is a teenager with no toothache is 0.1."

Represent in first order logic

⇒ $p(\text{cavity} / \text{teenager} \wedge \neg \text{toothache}) = 0.1$

Probability Distribution:

The probability of all possible values of a random variable.

eg. Weather = {sunny, rainy, cloudy, snow}

$P(\text{Weather} = \text{sunny}) = 0.6$

$P(\text{Weather} = \text{rainy}) = 0.1$

$P(\text{weather} = \text{cloudy}) = 0.29$

$P(\text{Weather} = \text{snow}) = 0.01$

$P(\text{Weather}) = \{0.6, 0.1, 0.29, 0.01\}$

↳ Bales Sys

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⇒ Inclusive - Exclusive principle:

$$P(a \vee b) = P(a) + P(b) - P(a \wedge b)$$

⇒ Fully Joint Probability Distribution:

↳ The probability of all possible worlds can be described using full joint probability distribution.

World
① weather
② cavity
③ Queue

eg. Weather - {sunny, rainy, snow, cloud}

Cavity = {cavity, ¬cavity}

The above two variables are independent variable.

eg.

	toothache		¬ toothache	
	catch	¬catch	catch	¬catch
cavity	0.108	0.012	0.072	0.008
¬cavity	0.016	0.064	0.144	0.576

- To determine the probability of preposition cavity and toothache.

$$\Rightarrow P(\text{cavity} \wedge \text{tootache}) = \overbrace{0.108 + 0.012 + 0.072 + 0.008}^{\text{cavity}}$$
$$+ \underbrace{0.016 + 0.064}_{\text{toothache}}$$

=

⇒ Inclusive - Exclusive principle:

$$P(a \vee b) = P(a) + P(b) - P(a \wedge b)$$

⇒ Fully Joint Probability Distribution:

↳ The probability of all possible worlds can be described using full joint probability distribution.

World
① weather
② cavity
③ Queue

eg. Weather = { sunny, rainy, snow, cloud }

Cavity = { cavity, ¬cavity }

The above two variables are independent variable.

eg.)

	toothache		¬toothache	
	catch	¬catch	catch	¬catch
cavity	0.108	0.012	0.072	0.008
¬cavity	0.016	0.064	0.144	0.576

– To determine the probability of preposition cavity and toothache.

$$\Rightarrow P(\text{cavity} \wedge \text{tootache}) = \underbrace{0.108 + 0.012 + 0.072 + 0.008}_{\text{cavity}} + \underbrace{0.016 + 0.064}_{\text{toothache}}$$

=

Independent Events:

when 2 events are independent the occurence of one event does not change the probability of ~~the~~ an other event.

Dependent event

when 2 events are dependent the outcome of the 1st event influences the outcome of the 2nd event.

eg. There are 3 green marbles and 3 blue marbles in a bag. Two marbles are drawn from the bag at random.

Let G be the event that the 1st marble draw is Green, and B be the event that the 2nd marble drawn is blue.

Statistics → on own

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Independent event	Dependent event
$P(G) = 3/6$	$P(G) = 3/6$
then the ball is placed back	then the ball is not placed back
$P(G) = 3/6$	$P(G) = 2/5$
$P(G) = 3/6$	$P(G) = 1/4$

Joint Probability Distribution:

- It is a statistical measure that calculates the likelihood of two events occurring together and at the same point of time $P(X \cap Y)$

Marginal Probability

- It is the probability of occurrence of a single event.

eg. 1) HBO cable networks takes a survey of 500 subscribers to determine the peoples favorite show. This is the info.

	Male	Female	Total
GOT	80	120	200
Westworld	100	25	125
others	50	125	175
Total	230	270	500

Probability Distribution:	Male	Female	Total
GOT	$\frac{80}{500} = 0.16$	$\frac{120}{500} = 0.24$	0.4
WW	$\frac{100}{500} = 0.2$	0.05	0.25
Others	0.1	0.25	0.35
Total	0.46	0.54	1

What is the probability of subscriber being male and prefering westworld?

⇒ Joint probability: $P(M \cap WW) = 0.2$

What is the probability of subscriber preferring Westworld?

⇒ Marginal Probability: $P(WW) = 0.25$.

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Conditional probability :
Probability of event A given event B = $P(A/B)$

Joint Probabity : Prob of event A and B

Marginal Probability : Prob of single event.

eg2) Consider a college applicate who has determined that he has 0.80 probabity of acceptance and that 60% of accepted student will recieve dormitary housing. what is the chance of student being accepted & recieving dormitary

$\Rightarrow$ $P(\text{acceptance}) = 0.8$ | $\neg P(\text{accepted}) = 0.2$

$P(\text{housing}) = \frac{60}{100} = 0.6$ | $\neg P(\text{housing}) = 0.4$

$P(\text{accepted} \wedge \text{dormitory}) = 0.8 \times 0.6 = 0.48$

eg3) $P(\text{acceptance}) = 0.8$, $P(\text{housing}) = 0.6$.
Given the 80% will have atleast 1 roomate.
Find the probability of being accepted and having dormitary and no roomate.

$\Rightarrow$ $P(\text{atleast 1 roomate}) = \frac{80}{100} = 0.8$

$P(\text{no roomates}) = \neg P(\text{atleast 1 roomate}) = 1 - 0.8 = 0.2$

$P(\text{accept} \wedge \text{dormitory} \wedge \text{no roomates}) = \underset{P(\text{accepted})}{0.8} \times \underset{P(\text{housing})}{0.6} \times \underset{P(\text{no roomate})}{0.2}$

$= 0.48 \times 0.2$

$= 0.096$

$0.48 \times 0.2 = 96 \times 10^{-3}$

Bayes Theorem

$\underset{\text{Hypothesis}}{\overset{\text{Posterior Probability}}{P(A/B)}} = \frac{\overset{\text{evidence}}{P(B/A)}_{\text{likelihood}} \cdot \overset{\text{prior prob}}{P(A)}}{P(B)_{\text{marginal evidence}}}$

$$\boxed{P(A/B) = \frac{P(B/A) \cdot P(A)}{P(B)}}$$

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To calculate Bayes Thm we need to find 3 probabilities.

① P(A) ⇒ Prior Probability
Probability of hypothesis before getting evidence.

② P(B) ⇒ Probability of evidence.

③ P(B/A) ⇒ Probability of evidence given that hypothesis is true.

eg. 1) ~~You are planning a picnic~~ today, but the morning is cloudy. 50% of all rainy days start of cloudy. Cloudy morning are common: 40% of days start off cloudy. And this is usually a dry month. Only 3 of 30 days tend to be rainy i.e 10%. What is the chance of rain during the day.

⇒ $P(cloudy/rainy) = \frac{50}{100} = 0.5$

$P(cloudy) = \frac{40}{100} = 0.4$

$P(rainy) = \frac{3}{30} = 0.1$ or $= \frac{10}{100} = 0.1$

$P(rainy/cloudy) = ?$

$$P(rainy/cloudy) = \frac{P(cloudy/rainy) \times P(rainy)}{P(cloudy)}$$

$$= \frac{0.5 \times 0.1}{0.4}$$

$$= 0.125$$

$\frac{\cdot 0.5}{4}$ $\frac{5}{40}$

eg. 2) Dangerous fires are rare (1%) but smoke is fairly common (10%) and 90% of dangerous fire make smoke. What is the prob of dangerous fire when there is smoke?

⇒ $P(\underset{A}{dangerous\ fire}) = \frac{1}{100} = 0.01$

$P(\underset{B}{smoke}) = \frac{10}{100} = 0.1$

$P(\underset{B}{smoke}/\underset{A}{dangerous fire}) = \frac{90}{100} = 0.9$

$P(\overset{A}{dangerous\ fire}/\overset{B}{smoke})$

$$= \frac{P(\overset{B}{smoke}/\overset{A}{dang\ fire}) \times P(\underset{A}{dang})}{P(\underset{B}{smoke})}$$

$$= \frac{0.9 \times 0.01}{0.1}$$

$$= 0.09$$

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eg. 03) Dr. Foster remembers to take his umberella 80% of days. It rains on 30% of days when he remembers to take his umbrella. And it rains on 60% of days when he forgets to take his umbrella. What is the probability that he remembers to take his umbrella when it rains?

$\Rightarrow$ $P(\text{umbrella}) = \frac{80}{100} = 0.8$

$P(\text{rain}/\text{umbrella}) = \frac{30}{100} = 0.3$

$P(\text{rains}/\sim\text{umbrella}) = \frac{60}{100} = 0.6$

$P(\text{umbrella}/\text{rains}) = \frac{\overbrace{P(\text{rain}/\text{umbrella}) \times P(\text{umbrella})}^{P(\text{rain} \cap \text{umbrella})}}{P(\text{rains}) \to ?} = ?$

$P(\text{rain}) = P(\text{rain}/\text{umbrella}) \times P(\text{umbrella}) + \underbrace{P(\text{rain}/\sim\text{umberella}) \times P(\sim\text{umbrella})}_{P(\text{rain} \cap \sim\text{umbrella})}$

$= 0.3 \times 0.8 + 0.6 \times 0.2$

$= 0.24 + 0.12$

$= 0.36$

$P(\text{umbrella}/\text{rains}) = \frac{0.3 \times 0.8}{0.36} = \frac{0.24}{0.36} = \frac{2}{3} = 0.667$

Bayers Thm with three or more events

$P(A_1/B) = \frac{P(A_1) \times P(B/A_1)}{P(A_1) \cdot P(B/A_1) + P(A_2) \cdot P(B/A_2) + P(A_3) \cdot P(B/A_3) + \dots P(A_n) \cdot P(B/A_n)}$

eg. 1) An art competition has 3 entries:
Scott puts in 15 paintings, 4% of his works have won first prize
Lubber puts in 5 paintings, 6% of his works have won first prize
Harato puts in 10 paintings, 3% of his works have won first prize
What is the prob that scott will win First prize?

$\Rightarrow$ Scott $\to$ S | First $\to$ B
Lubber $\to$ L
Harato $\to$ H

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$P(S/F) = ?$

$$P(S/F) = \frac{P(S) \times P(F/S)}{P(S) \times P(F/S) + P(L) \times P(F/L) + P(H) \times P(F/H)}$$

$P(F/S) = 4\% = \frac{4}{100} = 0.04$	$P(S) = 15/30$ $\hookrightarrow 15+5+10$
$P(F/L) = 6\% = \frac{6}{100} = 0.06$	$P(L) = 5/30$
$P(F/H) = 3\% = \frac{3}{100} = 0.03$	$P(H) = 10/30$

$$P(S/F) = \frac{15/30 \times 0.04}{15/30 \times 0.04 + 5/30 \times 0.06 + 10/30 \times 0.03}$$

$$= \frac{15 \times 4}{15 \times 4 + 5 \times 6 + 10 \times 3}$$

$$= \frac{60}{60 + 30 + 30}$$

$$= \frac{60}{120}$$

$$= \frac{1}{2} = 0.5$$

$\therefore$ Scott has 0.5 prob of winning first place.

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imp
6mks

Bayesian Belief Network.

- It is a directed graph in which each node is ~~[illegible]~~ annotated with quantitative probability information. ~~[illegible]~~ eg.

OR

- BBN is a probabilistic model that represents conditional dependency between random variable through a directed acylic graph.
The graph consists of nodes and edges. The nodes represent variables which can be discrete or continuous
The arcs represent relationship among the variables.

Planning → DDT(something)
Total order Planning → Forward & Backward state space search
Partial order Planning.

If question asked on conditional use BSL

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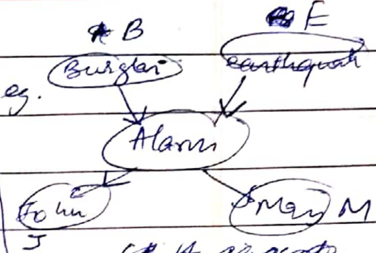
Bayesian Belief Network (BBN)

eg.



~~Cliff glypsop aloud~~

P(A/BE)
Alarm BorE

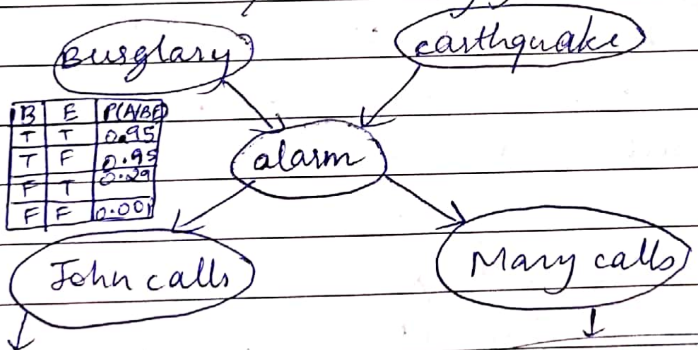
P(J/A) calls cops.
P(M/A)

eg. Description of problem :

You have installed a new burglar alarm at home. It is fairly reliable at detecting a burglary but also responds on occasion of earthquakes.
Two neighbours John & Mary who have promised to call the owner at work when they hear the alarm. John always calls when he hears the alarm but sometimes confuses the telephone ringing with the alarm & calls the owner. Mary on the other hand likes load music & sometimes missed the alarm all together.
Given the evidence of who has or hasn't called we would like to estimate the probability of ~~a~~ burglar.

P(B)
0.001

P(E)
0.002



B	E	P(A/BE)
T	T	0.95
T	F	0.95
F	T	0.29
F	F	0.001

A	P(J/A)
T	0.90
F	0.05

A	P(M/A)
T	0.70
F	0.01

Q. What is the prob that ~~an~~ alarm has sounded but neither a burglary nor a earthquake has occurred & Both mary & John calls.

⇒)

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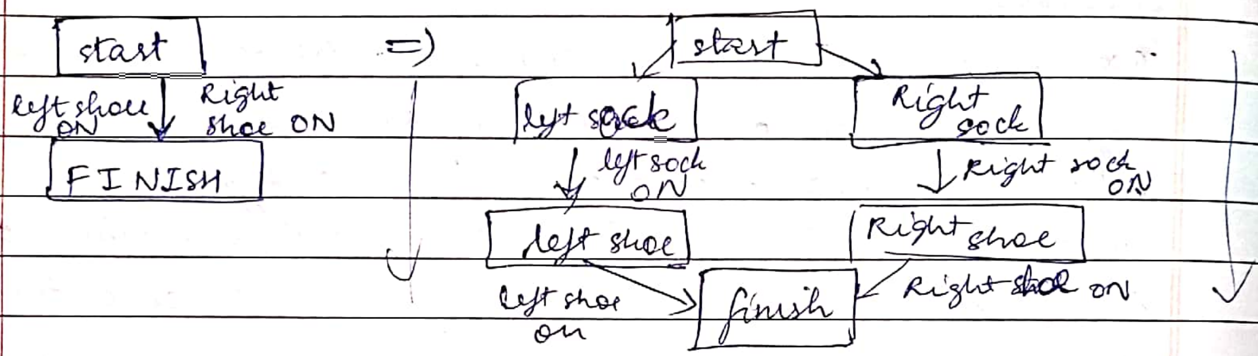
Partial Order Planning:

→ works on several subgoals independently
→ solves them with subplanes
→ combine the subplanes.
→ flexibility in ordering the subplans
→ least commitment strategy



Partial order has 4 components:

① set of Actions
↳ Steps of plan
↳ Action performed to achieve Goal
eg. {start, left sock, left shoe, right sock, right shoe, finish}

② ~~Set~~ Set of ordering precondition
↳ They are ordering constraint without performing action 'x' we cannot perform action 'y'.
eg. {Right Sock < Right Shoe, left sock < left shoe}

③ set of casual links
↳ which actions meets which precondition of other action
↳ provides link from outcome of one step to precondition of another
eg. leftsock → left Sock ON → left shoe.

④ set of open preconditions
↳ specifies the precondition not fulfilled
↳ For solution → open precondition is empty.

eg. if left sock missing: left sock ON precondition is open
& left shoe also is open.
Cannot reach finish

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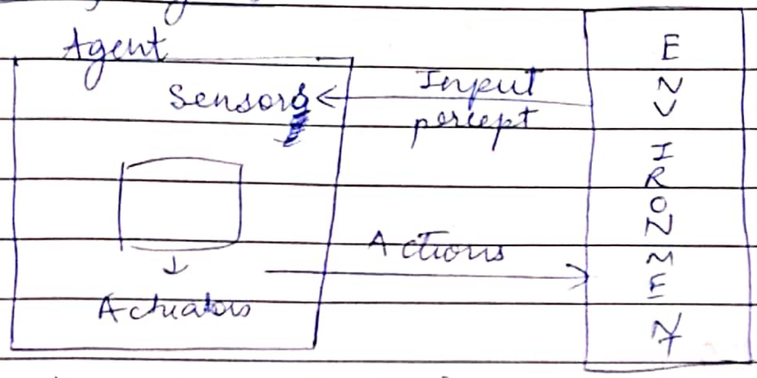
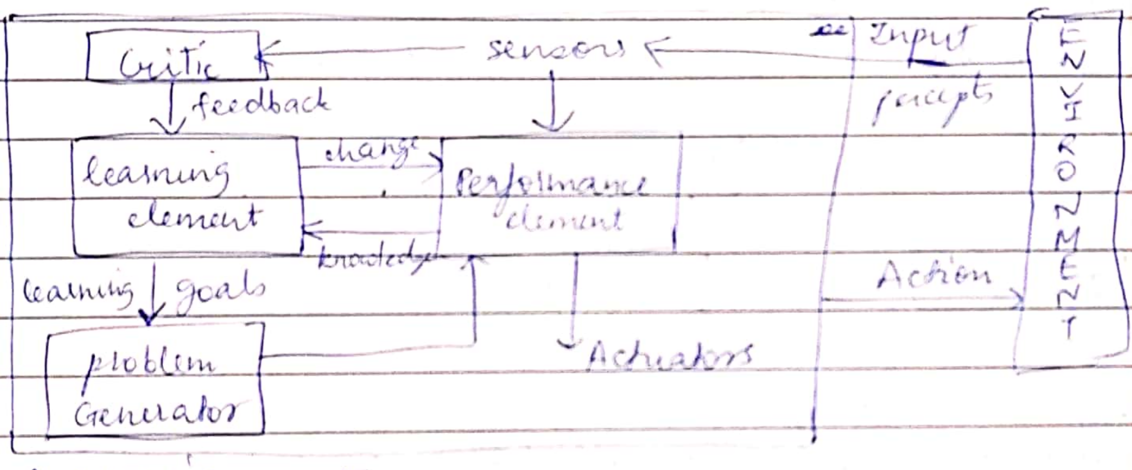
Learning Agents:



Agent percieves its environment through its sensors & acts upon that environment through its actuators.



learning agent.

Performance element:
- Based on I/P recived from sensors and learning element
- chose action to act external environment.

Critic :
- compares sensor I/P
- compares with standard performance
- Generate feedback

Learning element:
- learning element learns from mistake
- understand expected behavior and enhanced standard

A

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Problem Generator
↳ suggest new or alternative actions
↳ will lead to new and instructive understanding

⇒ Actuators are the one who takes action

Types of learning:

Learning.
⇒ A machine is said to be learning from past experience (data fed in) w.r.t some class of task if its performance in the given task improves with experience.

Types of learning
- Supervised
- Unsupervised
- Reinforcement

(1) Supervised learning:
↳ we have I/P as well as O/P (Training Data)
↳ labelled Dataset
↳ Testing Data, Training Data.
↳ Measure how algorithm will perform accurately with labelled Data

Types of supervised learning
(a) classification

Binary classification
0 or 1

Multiclass classification
eg: emails: social, promotional, spam, inbox ....

i/p
o/p

UserID	Gender	age	Salary	Purchased
1	M	23	30,000	1
2	F	21	40,000	0
3	F	22	60,000	1
4	M	24	30,000	1
5	M	40	60,000	[illegible]

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(Dataset is needed for ~~every~~ learning.) → My own.

(6) Regression
↳ o/p have continuous value.
(changes regularly over time) — wind speed.

Temp	pressure	Humidity	windDirection	windspeed.

eg if pressure out of range something is wrong.

eg 10-20 sudden change 100 ⇓ storm will come maybe.

(ii) Unsupervised learning.
↳ Training model → raw/unlabelled Data
↳ Identify patterns, trends in Data
↳ Cluster similar Data into groups.

Clustering
↳ inherent grouping
eg. Grouping customers by purchasing behavior.

Association
↳ rules that describe portion of Data
eg people that buy x will buy y

Association??
Unsupervised learning → eg (1) Field of diff animals.
↳ Told to seperate them.
↳ Here you will cluster them based on features/patterns/looks/characteristics.
eg. Humps → camel
spots → cheetah ...

clustering??
eg (2) In Rainy season → Raincoat / Umbrella Trend
∴ TV will promote these in Rainy season.
↳ Trend?

(i) Supervised learning.

→ Decision Trees

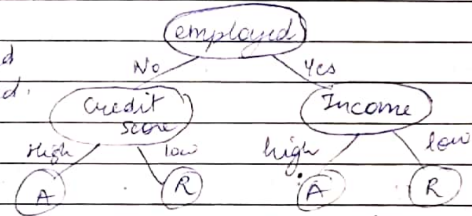
→ Used for classification & Regression.

→ classifier (Trees structured)

→ Two nodes → Decision node → Attribute
→ leaf node → actual o/p.

eg.

A - Approved
R - rejected.



1) A person is employed and his income is very low
∴ Rejected

2) A person is not employed and the credit score is very high.
∴ Approved

⇒ Entropy H(S)

→ Finite set S

→ measure of amount of uncertainity or randomness in Data

→ Tells us about predicatability of certain events.

eg. Toss a coin : P(H) = P(T) = 0.5 ∴ Uncertainity = 0.5.

lower value → less uncertainity
higher value → high uncertainity.

If 2 headed coin Uncertainty of head = 0

→ Entropy is denoted by H(S) & is given by

2) ~~Information Gain~~

$$\boxed{\begin{aligned} H(S) &= -P(+) \times \log_2 P(+) - P(-) \times \log_2 P(-) \\ &= -[P(+) \times \log_2 P(+) + P(-) \times \log_2 P(-)]. \end{aligned}}$$

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