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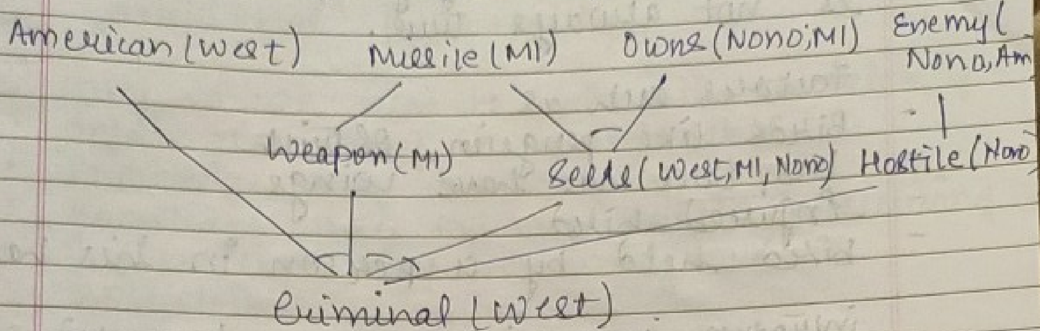
Forward chaining.
Col. West is criminal proof.



⇒ FC is data-driven, automatic, unconscious processing
BC is goal driven, appropriate for problem solving & has lesser complexity.

⇒ $\exists x$ Dog(x) ^ Owns(Jack, x)
$\forall x$ ($\exists y$ Dog(y) ^ Owns(x, y)) → AnimalLover(x)
$\forall x$ AnimalLover(x) → ($\forall y$ Animal(y) → ¬Kills(x,y))
Kills(Jack, Tuna) ∨ Kills(Curiosity, Tuna)
Cat(Tuna)
$\forall x$ Cat(x) → Animal(x)

~~30/8/19~~
9/9/19

Dealing with uncertainity in AI
We need to provide a no. of facts (universal) in the knowledge base. We cannot ignore them just because they haven't been explicitly mentioned.

But, there may exist uncertainity in

Case Base reasoning

rules.

$\forall_x$ bird(x) → fly(x)

is not always true.

Factors such as:

- Birds like penguin, ostrich
- has/does not have wings
- Injured bird
- bird held by a person in his hands

introduce uncertainity in the knowledge base.
Rules cannot (may not) always be true

Thus, we can keep a portion for accomodating uncertainity in every rule.

Ex:

$\forall_x$ bird(x) ^ ¬P(x) ^ ¬O(x) ^ ¬K(x) ^ has_wings(x) → ~~bird~~ fly(x) [80%]

(P → penguin, O → ostrich, K → kiwi)

20% kept aside for uncertainity, i.e. this rule yields correct ans. in 80% cases only

can occur due to lack of knowledge or lack of info. provided by user or misrepresentation.

<u>Dealing with uncertainty</u>

- Probability
- Fuzzy logic
- Neural network
- Hidden markup model

Probability of P1 event given the occurance of event P2 is called conditional probability.

12/9/19

Why do we need to deal with uncertainty?

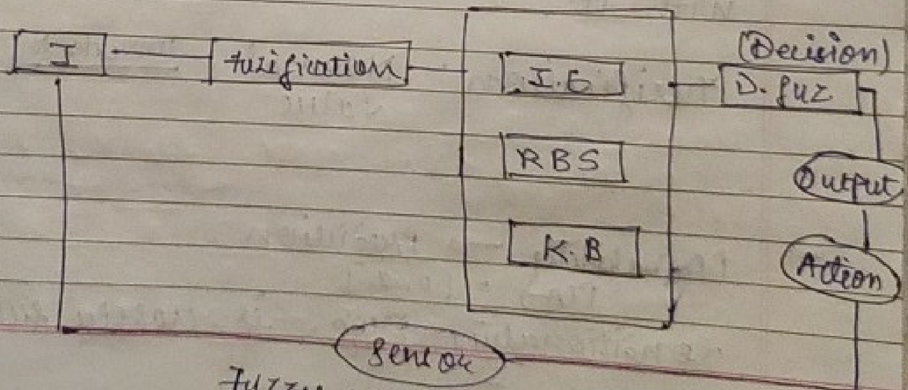
- Information may be questionable.
- Knowledge may be questionable.
- Knowledge may not be truth preserving.
- Information may be ambiguous or uncertain
- Output is expected in probability.

Sources of uncertainty

* Uncertain data (Inicomplete data)
* Uncertain knowledge
* Knowledge representation technique.
* Inference techniques

Methods to Deal with uncertainty

* Fuzzy logic
* Probabilistic model
* Hidden markov model
* Neural network
* Certainty factor with quantitative F.L



Fuzzy control system

Conditional probability:

$$P\left(\frac{A}{B}\right) = \frac{P(A \cap B)}{P(B)}$$

$$P\left(\frac{B}{A}\right) = \frac{P(A \cap B)}{P(A)}$$

Fuzzy Logic

Degree of membership

Temperature

10° 15° 20° 25° 30° 35° 40° 45° 50°

→ cold → cool → Average

→ warm → hot → very hot

Degree of membership depicts the probability of an item to belong to class A.

If only two classes : full and empty are ~~presented~~, then probability or degree of membership of each is roughly around 0.5.

Every object has a probabilistic ~~or~~ value based on fuzzy value associated with it.

Fuzzification : Normal value $\xrightarrow{\text{converted to}}$ Fuzzy set value (hot/cool) etc.

→ Probability → Prediction.

$P(A) = [0, 1]$

conditionality prob. is closely related to the dependency between two entities.

$$P(A \cap B) = P\left(\frac{A}{B}\right) * P(B)$$

Also, $P(A \cap B) = P\left(\frac{B}{A}\right) * P(A)$

$$\therefore P\left(\frac{A}{B}\right) * P(B) = P\left(\frac{B}{A}\right) * P(A)$$

$$\Rightarrow P\left(\frac{A}{B}\right) = \frac{P(B/A) * P(A)}{P(B)}$$

when given the prob. of B occuring when A has occured, we can determine the reverse dependency by using the above formula.

13/9/19 Representation of fuzzy set.

i) $A = \{(10, 0.1), (15, 0.3), \dots\}$

member ↑ degree of membership towards A

$\therefore \mu_{10}^{(A)} = 0.1$

ii) $A = \left\{\frac{0.1}{10} + \frac{0.3}{15} + \dots\right\}$

DOM member

⇒ Set towards with DOM of every variable is 0 is an empty fuzzy set.
DOM of every variable 1 is universal fuzzy set.

$$\Rightarrow A = \left\{\frac{0.1}{10} + \frac{0.2}{20} + \frac{0.3}{30} + \frac{0.8}{70}\right\}$$

$$B = \left\{ \frac{0.3}{15} + \frac{0.1}{20} + \frac{0.9}{35} + \frac{0.8}{20} \right\}$$

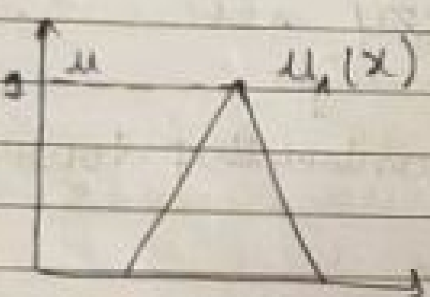
$$\min(A \wedge B) = \{\min(\mu_x(A, B))\}$$

Here, $\min(A \wedge B) = \left\{ \frac{0}{10} + \frac{0}{15} + \frac{0.1}{20} + \frac{0}{30} + \frac{0}{35} + \frac{0.8}{70} \right.$

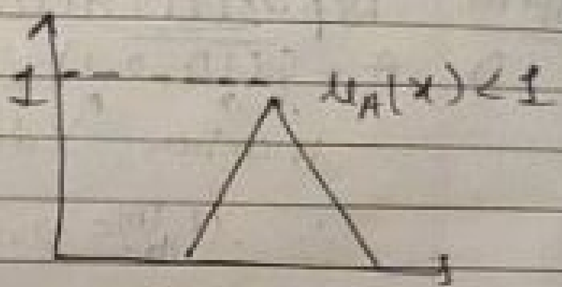
$$= \left\{ \frac{0.1}{20} + \frac{0.8}{70} \right\}$$

Empty Fuzzy Set: $\mu_A(x) = 0$.

Normal FS: A normal FS is one whose membership func. has at least one element x in the universe where its membership func. equals 1



Normal FS.



Sub normal FS

Equality of FS: $\mu_A(x) = \mu_B(x)$

Union of two FS:

$$\mu_{A \cup B}(x) = \max[\mu_A(x), \mu_B(x)]$$

$$A = \left\{ \frac{1}{2} + \frac{0.5}{3} + \frac{0.3}{4} + \frac{0.2}{5} \right\}$$

$$B = \left\{ \frac{0.5}{2} + \frac{0.7}{3} + \frac{0.2}{4} + \frac{0.4}{5} \right\}$$

$$\mu_{A \cup B} = \left\{ \frac{1}{2} + \frac{0.7}{3} + \frac{0.3}{4} + \frac{0.4}{5} \right\}$$

Intersection :

crisp set – which ele belongs to both sets?

Fuzzy set – How much of the ele. is in both sets?

$\Rightarrow$ $A \{ (x_1, 0.8), (x_2, 1), (x_3, 0.2), (x_4, 0.5), (x_5, 0.6), (x_6, 1) \}$

$B \{ (x_2, 0), (x_3, 1), (x_5, 1), (x_6, 0.2), (x_7, 0.8) \}$

$A \cup B = \{ (x_1, 0.8), (x_2, 1), (x_3, 1), (x_4, 0.5), (x_5, 1), (x_6, 1), (x_7, 0.8) \}$

$A \cap B = \{ (x_3, 0.2), (x_5, 0.6), (x_6, 0.2) \}$

$\Rightarrow$ $A = \left\{ \frac{0.8}{1} + \frac{0.75}{2} + \frac{0.90}{3} + \frac{0.99}{4} + \frac{1}{5} \right\}$

$$\bar{A} = 1 - \mu_A(x)$$

$$\bar{A} = \left\{ \frac{0.2}{1} + \frac{0.25}{2} + \frac{0.1}{3} + \frac{0.01}{4} + \frac{0}{5} \right\}$$

complement of a set.

$\Rightarrow$ Product of two FS.

$$\mu_{A.B}(x) = \mu_A(x) \cdot \mu_B(x)$$

16/9/19 1) Strong α-cut : $A_\alpha = \{ x \mid \mu_A(x) > \alpha \}$

Weak α-cut : $A_\alpha = \{ x \mid \mu_A(x) \geq \alpha \}$

2) Support of fuzzy set

$support(x) = \{x \mid \mu_A(x) > 0\}$

3) Core of a fuzzy set

$core(A) = \{x \mid \mu_A(x) = 1\}$

4) Height. $h(A)$ = is the largest value of $\mu_A(x)$ for which α-cut is not empty

[Result of above 4 op. will be a CRISP set]

Fuzzy set :

$A \cap \bar{A} \neq \phi$

$A \cup \bar{A} \neq 1$

$(A \cap B)' = A' \cup B'$

$(A \cup B)' = A' \cap B'$

Ex: $A = \left\{ \frac{0.2}{1} + \frac{0.3}{3} + \frac{0.6}{4} + \frac{0.9}{7} + \frac{1}{8} \right\}$

$\alpha = 0.5$

Strong α-cut

$A_{0.5} = \{4, 7, 8\}$.

$\alpha = 0.3$

Weak α-cut

$A_{0.3} = (4, 7, 8)$ // Strong α-cut

$A_{\overline{0.3}} = (2, 4, 7, 8)$ / Weak α-cut

$\Rightarrow A = \left\{ \frac{0.1}{2} + \frac{0.4}{3} + \frac{0}{4} + \frac{0.5}{6} + \frac{0}{8} + \frac{1}{9} \right\}$

$supp(A) = (2, 3, 6, 9)$

Fuzzy singleton & If the support of A has only one variable in the crisp set and its DOM is 1 then it is called fuzzy singleton.

$supp(A) = (x) \quad \& \quad \mu_A(x) = 1$

$\Rightarrow A = \left\{ \frac{0.2}{x_1} + \frac{0.9}{x_2} + \frac{1}{x_3} + \frac{0.8}{x_4} + \frac{1}{x_5} + \frac{0.9}{x_6} \right\}$

$core(A) = (x_3, x_5)$

$\Rightarrow A = \left\{ \frac{0.3}{a} + \frac{0.2}{b} + \frac{0.4}{c} + \frac{0.1}{d} + \frac{0.6}{e} \right\}$

$h(A) = 0.6$

$\Rightarrow$ Fuzzy operations

Cartesian Multiplication

$C = A \times B$

$= \left[\mu_c(x) / (a,b) \mid a \in A, b \in B, \mu_c(x) = \min(\mu_A(a), \mu_B(b)) \right]$

$A = \frac{0.2}{3} + \frac{1}{5} + \frac{0.5}{7} \; ; \; B = \frac{0.8}{2} + \frac{0.3}{6}$

$A \times B = [\min((0.2),(0.8))/(3,2),$

$\min((0.2),(0.3))/(3,6)$

$\min((1, 0.8))/(5,2),$

$\min((1, 0.3))/(5,6),$

$\min((0.5, 0.8))/(7,2),$

$\min((0.5, 0.3))/(7,6)]$

$= \frac{0.2}{(3,2)} + \frac{0.2}{(3,6)} + \frac{0.8}{(5,2)} + \frac{0.3}{(5,6)} + \frac{0.5}{(7,2)} + \frac{0.3}{(7,6)}$

$$\Rightarrow x = \frac{0.6}{3} + \frac{0.7}{8} + \frac{0.9}{9} + \frac{1}{10}$$

$$y = \frac{0.5}{2} + \frac{0.4}{3}$$

$$z = x \times y$$

$$= \left[\frac{0.5}{(3,2)} + \frac{0.4}{(3,3)} + \frac{0.5}{(8,2)} + \frac{0.4}{(8,3)} + \frac{0.5}{(9,2)} + \frac{0.4}{(9,3)} + \frac{0.5}{(10,2)} + \frac{0.4}{(10,3)} \right]$$

$$\Rightarrow A.B = \mu_A(x).\mu_B(x)/x \mid x \in A, x \in B$$

Ex: $A = \frac{0.2}{3} + \frac{1}{5} + \frac{0.5}{7}$

$$B = \frac{0.1}{3} + \frac{0.3}{7} + \frac{0.2}{8}$$

$$A.B = \frac{(0.2)(0.1)}{3} + \frac{(1)(0)}{5} + \frac{(0.5)(0.3)}{7} + \frac{(0.2)(0)}{8}$$

$$= \frac{0.02}{3} + \frac{0.15}{7}$$

$\Rightarrow$ Exponent of A

$$A^\alpha = \{ \mu_A(x)^\alpha / x \mid x \in A \}$$

Ex: $A = \frac{0.5}{4} + \frac{1}{5} + \frac{0.4}{6}$

$$A^2 = \frac{(0.5)^2}{4} + \frac{(1)^2}{5} + \frac{(0.4)^2}{6}$$

$$= \frac{0.25}{4} + \frac{1}{5} + \frac{0.16}{6}$$

Algebraic sum

$A \hat{+} B = \mu_A(x) + \mu_B(x) - (\mu_A(x) \cdot \mu_B(x))$

Ex: $A = \frac{0.2}{1} + \frac{1}{2} + \frac{0.4}{3}$

$B = \frac{0.3}{1} + \frac{0.4}{2} + \frac{0.2}{7}$

19/9/19

$P(E|H)$ ← event

hypothesis

Bounded sum $(A \oplus B)$

$\mu_{A \oplus B}(x) = \min(1, \mu_A(x) + \mu_B(x))$

$\mu_{A \ominus B}(x) = \min(1, \mu_A(x) - \mu_B(x))$

→ Machines generally use CRISP dataset while, humans & rules tend to use fuzzy values.

Fuzzy control : combines use of fuzzy linguistic variables with fuzzy logic.

→ Fuzzy logic deals with imprecision and vagueness, but not uncertainty.

Contd... (Bcv site)

2/9/19

Box B_1	B_2
A A	O O
O O O O	A A A ~~A~~
(0.6 - prob. of choosing B1)	(0.4)

Joint Prob. Dist. (JPD):

		Fruit	
		F=O	F=A
Box	B=B1	0.4	0.2
	B=B2	0.24	0.16.

If we want to get the overall prob. of choosing an orange, we simply add the column (F=O). This is marginal probability.

→ If $P(A/B) = P(A)$, then events A & B are independent.

Ex: $P(B \mid J, \neg M, E, A)$

$$= \frac{P(B \wedge J \wedge \neg M \wedge E \wedge A)}{P(J \wedge \neg M \wedge E \wedge A)}$$

$P(J \wedge \neg M \wedge E \wedge A)$

$= P(J \mid \neg M \wedge E \wedge A) * P(\neg M \wedge E \wedge A)$

→ $P(C, A, B) = P(C \mid A, B) * P(A, B)$

$= P(C \mid A, B) * P(A \mid B) * P(B)$

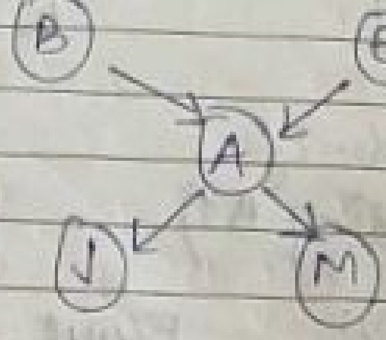
$\neg B, \neg E, A, J, M$

→ $P(\neg B \mid \neg E, A, J, M)$

independent of all other attr., so $P(B)$

$P(\neg B) * P(\neg E) * P(A \mid \neg B, \neg E) * P(\neg J \mid A) * P(\neg M \mid A)$

$P(B) = 0.001$



$P(E) = 0.002$

9|19

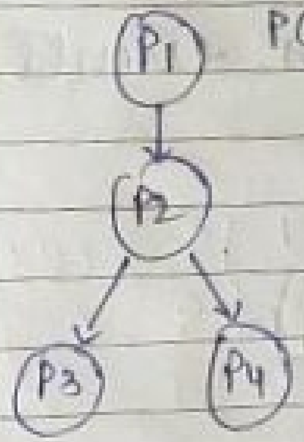
B	E	P(A)
T	T	0.95
T	F	0.95
F	T	0.29
F	F	0.001

A	P(J)
T	0.90
F	0.05

A	P(M)
T	0.70
F	0.01

(conditional Probability table)

2 →



$P(P1) = 0.4$

P1	P(P2)
T	0.8
F	0.5

P_2	$P(P_3)$
T	0.2
F	0.3

P_2	P(P4)
T	0.8
F	0.5

Finding joint probability = $P(B, E, A, J, M)$

$= P(B) * P(E) * P(A \mid B, E) * P(J \mid A) * P(M \mid A)$

Also, $P(J) = P(A) * P(J \mid A) + P(J \mid \neg A) * P(\neg A)$

$= P(J \cap A) + P(J \cap \neg A)$

$= 0.9 * P(A) + 0.05 * P(\neg A)$

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$P(A) = P(A|B,E) * P(B) * P(E) +$
$P(A|B,\neg E) * P(B) * P(\neg E) +$
$P(A|\neg B,E) * P(\neg B) * P(E) +$
$P(A|\neg B,\neg E) * P(\neg B) * P(\neg E)$
$= (0.95 \times 0.001 \times 0.002) +$
$(0.95 \times 0.001 \times 0.998) +$
$(0.29 \times 0.999 \times 0.002) +$
$(0.001 \times 0.999 \times 0.998)$
$= 0.00252$

$\therefore P(J) = (0.9 \times 0.0025) + (0.05 \times 0.9975)$
$= 0.0521$

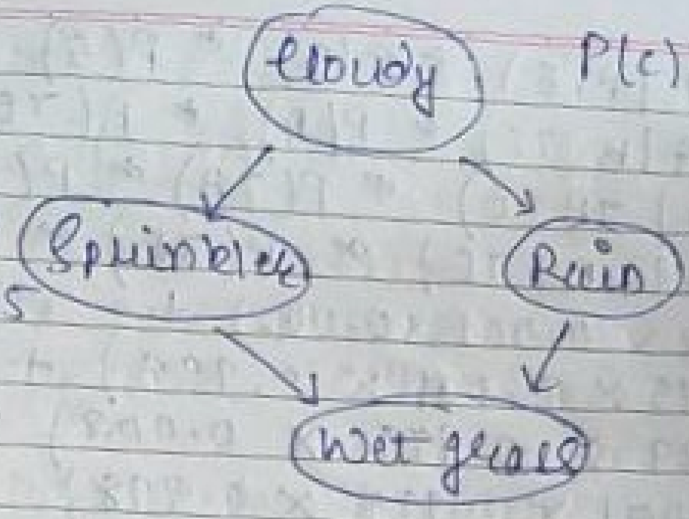
$P(M) = P(M|A) * P(A) + P(M|\neg A) * P(\neg A)$

$\Rightarrow$ Rule: $P(A,B) = P(A|B) * P(B)$

Q2. (i) $P(\neg P_3) = ?$
$= 1 - P(P_3)$
$P(P_3) = P(P_3|P_2) * P(P_2) + P(P_3|\neg P_2) * P(\neg P_2)$
$P(P_2) = P(P_2|P_1) * P(P_1) + P(P_2|\neg P_1) * P(\neg P_1)$
$= (0.8 \times 0.4) + (0.5 \times 0.6)$
$= 0.32 + 0.3 = 0.62$
$P(P_3) = (0.2 \times 0.62) + (0.3 \times 0.38) = 0.238$
$\therefore P(\neg P_3) = 0.762$

(ii) $P(P_2|\neg P_3)$ (iii) $P(P_1|P_2,\neg P_3)$ (iv) $P(P_1|P_3,P_4)$

Q3. $P(C,R,S,W) = ?$
$P(R) = ?$
$P(W) = ?$



$P(C) = 0.5$

$P(S|C) = 0.1$
$P(S|\neg C) = 0.5$

$P(R|C) = 0.8$
$P(R|\neg C) = 0.2$

R	S	P(W)
T	T	0.99
T	F	0.9
F	T	0.9
F	F	0

Q4 $A \longrightarrow B \longrightarrow C$

$$P(C|B,A) = \frac{P(A,B,C)}{P(A,B)}$$

$$= \frac{P(A) * P(B|A) * P(C|B)}{P(A) * P(B|A)}$$

$$= P(C|B)$$

Q.2 (ii) $P(P_2 | \neg P_3) = P(P_2) = 0.62$
(iii) $P(P_1 | P_2, \neg P_3) = P(P1) = 0.4$
(iv) $P(P_1 | P_3, P_4) = P(P1) = 0.4$

Q.3 $P(C,R,S,W) = P(C) * P(R|C) * P(S|C) * P(W|R,S)$

$P(R|C) = 0.8$ $\quad P(S|C) = 0.1$

$P(W|R,S) = \cancel{P(W|R) * P(R)} = 0.99$

$\therefore P(C,R,S,W) = 0.5 \times 0.8 \times 0.1 \times 0.99$
$= 0.0396$

$$P(R) = P(R|C) * P(C) + P(R|\neg C) * P(\neg C)$$
$$= (0.8 \times 0.5) + (0.2 \times 0.5)$$
$$= 0.4 + 0.1 = 0.5$$

$$P(W) = P(W|R,S) * P(R) * P(S) +$$
$$P(W|R,\neg S) * P(R) * P(\neg S) +$$
$$P(W|\neg R, S) * P(\neg R) * P(S) +$$
$$P(W|\neg R, \neg S) * P(\neg R) * P(\neg S)$$

$$P(S) = P(S|C) * P(C) + P(S|\neg C) * P(\neg C)$$
$$= (0.1 \times 0.5) + (0.5 \times 0.5)$$
$$= 0.05 + 0.25 = 0.3$$

$$P(W) = (0.99 \times 0.5 \times 0.3) +$$
$$(0.9 \times 0.5 \times 0.7) +$$
$$(0.9 \times 0.5 \times 0.3) +$$
$$(0 \times 0.5 \times 0.7) = 0.5985$$

Non-monotonic reasoning

When we add some additional knowledge inside a rule ~~when~~ and the rule may not hold true for ~~all~~ that cases, it is called non-monotonic reasoning or logic.

Ex: $\forall_x \text{ bird}(x) \rightarrow \text{fly}(x)$. (hold true).

$\Downarrow$

$\forall_x \text{ bird}(x) \wedge \text{penguin}(x) \rightarrow \text{fly}(x)$ (untrue)

Monotonic logic.

If a rule is true, it will hold true for all cases even if we add some knowledge to it.

27/9/19 Frame Based Expert Systems.
- Type of Knowledge Representation Technique

Frame is a data structure with typical knowledge about a particular object or concept. (collection of slots)
Each frame has its own name and set of attributes associated with it.
Frames provide a means of organising knowledge in slots to describe various attr. & characteristics.
Slots are used to store values. It may contain a default value or pointer to another frame.

Info. in slots:
a) Frame name
b) Relationship of frame to other frames
c) Slot value
d) Default slot value
e) Range of slot value
f) Procedural info.

Script representation
Used to represent events.
Its components include:
i) Entry conditions : must be satisfied before events in the script can occur.

ii) Results
iii) Props
iv) Roles

v) Tracks
vi) Scenes.

Actions: ATRANS, PTRANS, PROPEL, MOVE, GRASP, INGEST, EXPEL, MTRANS, MBUILD, CONC, SPEAK, ATTEND

CONC ↑ conceptualize or think about an idea.

Ex: Restaurant Script

Script: Restaurant

Role: S = Customer C = Cook M = Cashier
W = Waiter O = Owner F = Food.

Track: Coffee Shop ~~Menu~~.

Props: Tables. Money.
Check. Menu

Scenes: Entering, Ordering, Exiting.

Advantages:
i) Capable of predicting implicit events.
ii) Single coherent interpretation may be build up from a collection of observations.

20/9/19

Search optimization → Random search, Informed, Uninformed

Random search → Evolutionary Computing

Evolutionary Computing → Genetic Algo., AC

Instead of going for every case, a case is picked up at random and it is evaluated. These are then compared to arrive at an optimal solution. This is the goal of random search.

Hence, in genetic algo:

generate population (randomly)

↓

Utility func
(Fitness func)

↓

Regenerate solution using population

Regeneration:

| | | | | | ... | | | 50 Solutions (population)

g (upper limit) (good) — b (lower limit) (bad).

Pick pairs: 1 g — 1 b → generate new solⁿ.

1 g - 1 g

1 b 1 b.

∴ population increases.

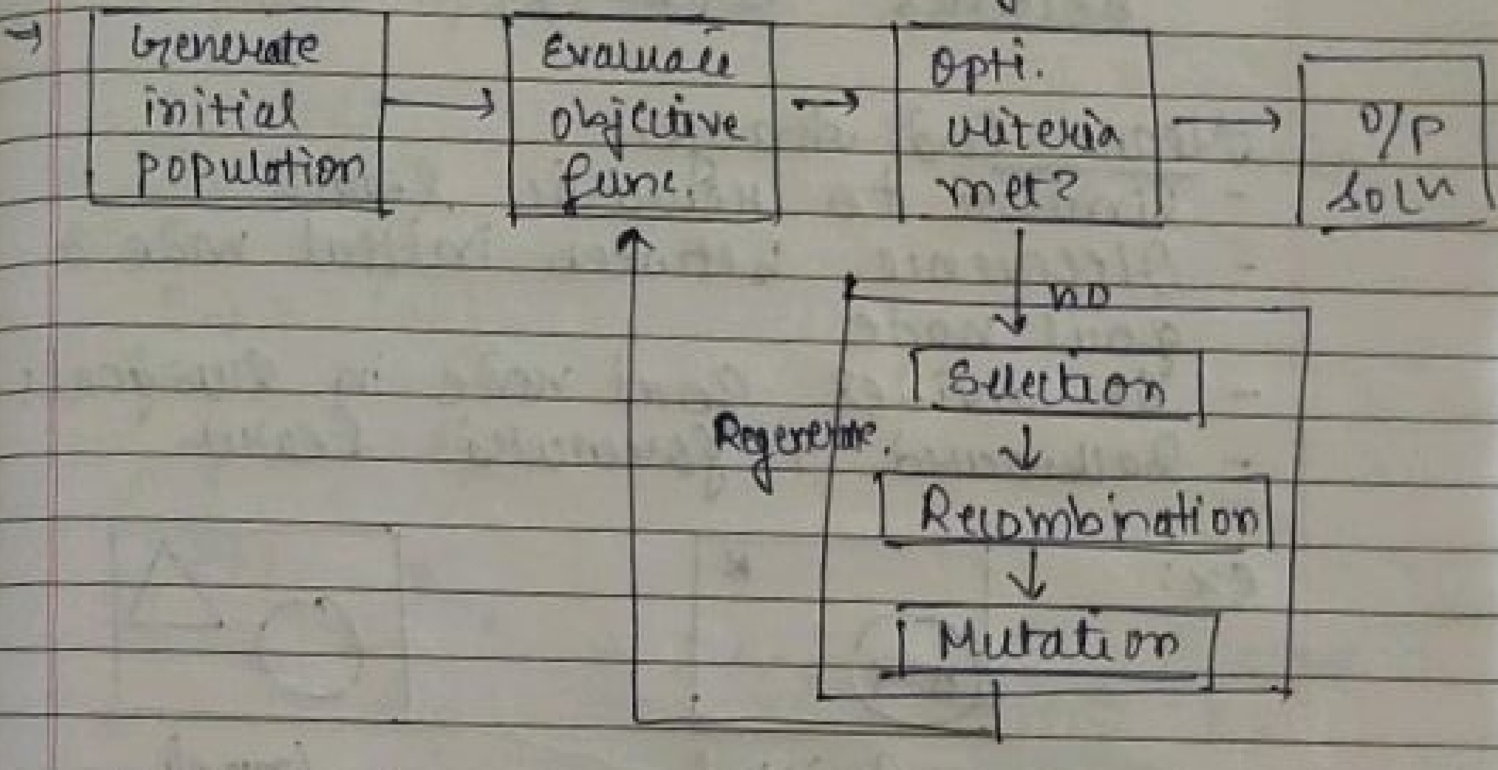
Further it is increased by changing the sequence of solⁿ

⇒ The main problem with the traditional

Search techniques is that they may end up with local optima rather than a global one.

Non-traditional: a) Genetic Algo.
b) Simmulated Annealing
c) Ant Colony optimization

Genetic Algo: Based on natural evolution of human genes.



Guided random search mechanism
↑ because we have a utility func to know whether a solⁿ is good/bad.

3/10/19 (1g) (1g)

crossover point

a	b
c	d

→

a	d
c	b

Mutation:

1	2	3	4	5

1	5	3	4	2

Problem solving techniques

Bidirectional search

- Blind search technique
- 2 Agents / algorithms
- Start from start node and simultaneously the end node
- When both coincide or arrive at a common solⁿ, the process ends.
- Depth = $d/2$ ∴ Time complexity becomes $O(b^{d/2})$

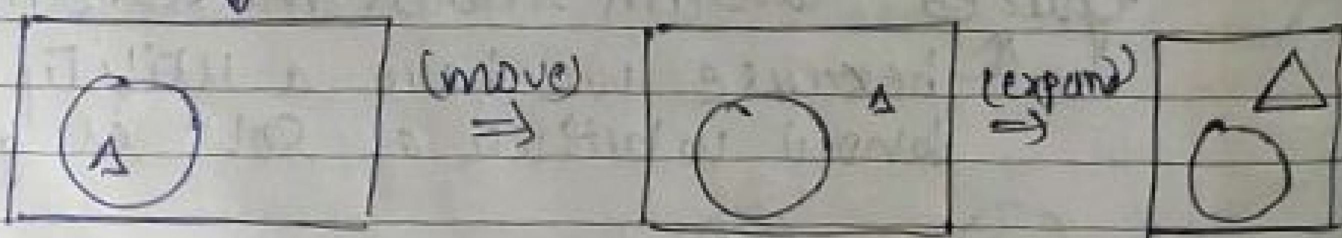
Means - End Analysis

- Similar to Heuristic search
- Difference between initial node & goal node
- It divides goal node in sub goals
- Backward + forward search.

Ex:

Initial Goal

(Remove)



Ex: Initial:

B
A C

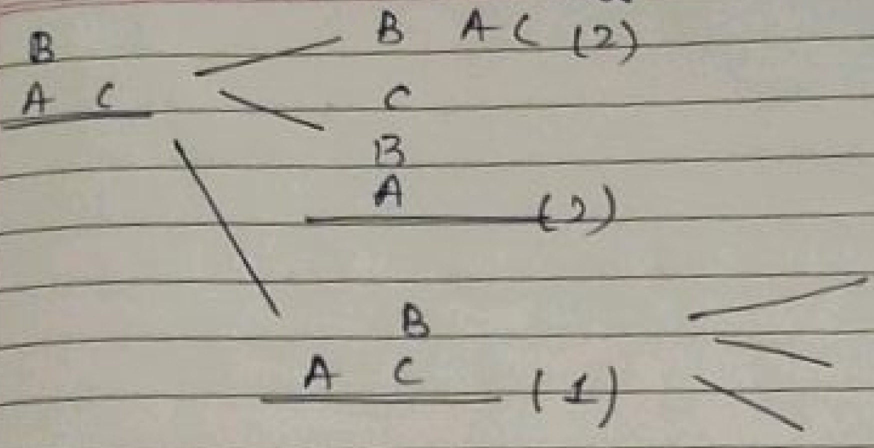
Goal:

B
C
A

Difference value: $\underset{(\text{A at correct place})}{0} + \underset{(\text{C on A})}{1} + \underset{(\text{B on C})}{1}$

$= 2$

diff.



Simulated Annealing

- Global optimization achieved.

$C = \text{init}$; $T = T_{max}$ to T_{min}

$E_c = E(C)$

$N = \text{Next}$

$E_N = E(N)$

$\Delta E = E_N - E_c$

if $(\Delta E > 0)$

$e = N$

else

$e^{\Delta E / T} > \text{rand}(0,1)$ ~~Else~~

$C = N$