Unit-3

Acting under uncertainty

Agent → (which) who is acting on the work.

Agent described any commitment that proportions are true, false are unknown. when agent knows enough facts about its enviornment, the logical approach enables it to derive plans that are guarnted to work. Unfortunately agents almost never have acces to the whole truth about their enviornment. Agent must, therefore act as under uncertainty.

For a logical agent, it might be impossible to construct a complete and correct description of how its action will work. if a logical agent cannot conclude that any particular course of action achieves its goal, then it will be unable to act.

Rational thing (decision) - The right thing to do.

Handling uncertain knowledge :-
(Nature of uncertain knowledge)

Let us take example of dental diagnosis using first order logic. Consider the following rule:

$$\forall P \ \text{Symptom}(P, \underbrace{\text{toothache}}_{\text{(Pain in one teeth)}}) \Rightarrow \text{Disease}(P, \text{cavity}).$$

The problem is that this rule is wrong. Not all patients with toothaches have cavities, some of have gum disease, an abcess, or several other problems.

$$\forall P \ \text{Symptom}(P, \text{toothache}) \Rightarrow \text{Disease}(P, \text{Cavity}) \lor \text{Disease}(P, \text{GumDisease}) \lor \text{Disease}(P, \text{Abcess}) \ldots$$

Unfortunatly, in order to make the rule true, we have to add an almost unlimited list of possible causes. we could try turning the rule into a causal rule.

$$\forall P \ \text{Disease}(P, \text{Cavity}) \Rightarrow \text{Symptom}(P, \text{Toothache})$$

But this rule is not right either, not all cavities cause pain.

Trying to use first order logic to cope with a domain like medical diagnosis thus fails for three reasons:-

1 Laziness -

2. Theoretical Laziness - Medical science has not complete theory for the domain.

3. Practical Ignorance - Sometimes, we might me uncertain about a particular work or operation.

The agent's knowledge can at best provide only a degree of belief in the relevant sentences. So our main tool for dealing with degrees of belief will be probability theory which assigns to each sentence a numerical degree of belief 0 to 1.

Probability provides a way of summarizing the uncertainty that comes from our Laziness & ignorance.

Degree of truth, as opposed to degree of belief, is the subject of fuzzy logic.

Before the evidence is obtained, we talk about prior or unconditional probability, after the evidence is obtained, we talk about posterior or conditional probability..

UNCERTAINTY AND RATIONAL DECISIONS :-

The presence of uncertainty radically changes the way an agent makes decisions.

PREFERENCES :- To make such choices, an agent must first have preferences between different possible outcomes of the various plans.

Decision theory = probability theory + utility theory.

We use utility theory to represent and reason with preferences (utility = "the quality of being useful")

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

LIMITATIONS OF MONOTONIC SYSTEMS:-

Logic based systems are monotonic in nature i.e. if a proposition is made which is true, it remains true under all circumstances. All theorems are proved to this methodology only. But in real life, all statments made do not necessarily mean that they are correct under the all circumstances.

Any statement is made by manipulating a set of beliefs. Experts predict, diagnose and perform majority of their mental ability by relying on their beliefs.

A monotonic reasoning system cannot work efficiently in real life enviornments because.

→ Information available is always incomplete.

→ As process goes by, situations change and so are the solutions.

→ Default assumptions are made in order to reduce the search time and for quick arrival of solutions.

BASIC CONCEPTS OF NON-MONOTONIC REASONING SYSTEMS-

AI systems provide solutions for those problems whose facts and rules of inference are explicitly stored in the database and knowledge base. But as mentioned above the data and Information are incomplete in nature and generally default assumptions are made.

FOR EXAMPLE

if we say that Rohini is a bird, the conclusion that is arrived at (default) is that Rohini can fly.

But on the other hand, it is not necessary that Rohini should fly because of a variety of reasons similar to those given below.

→ Rohini could be an Ostrich.

→ Rohini's wings are broken.

→ Rohini is too weak to fly.

→ Rohini could be caged.

→ Rohini could be a dead bird etc.

As one makes a statement like Rohini is a bird, people assume that it can fly. if another statement like Rohini is an ostrich, people retract the assumptions that were made.

Lot of day-to-day activities involve such instances wherein assumptions that have been made are forced to be withdrawn by the occurence of an event or by getting a new piece of information.

Based on the most likely characteristics one can make some statements like the following-

→ Indian Railways maintain punctuality.

→ Indian Airlines regularly operate their flights.

→ Letters are delivered in time.

→ Telephones are working properly and no cross talks.

GOLDEN RULES OF DEFAULT REASONING-

Guessing of an information is permitted as long as it does not contradict with the existing ones. Default reasoning assists in the generation of these guesses. To do so some rules are to be allowed.

The Golden Rules of default reasoning.

Let X be a piece of information and Y be a conclusion.

Rule 1:

if X is not Known, then conclude Y.

Rule 2:

if X cannot be proved, then conclude Y.

Rule 3:

if X cannot be proved in a fixed amount of time, then conclude Y.

CIRCUMSCRIPTION -

One important kind of reasoning is McCarthy's circumscription. To explain what is circumscription, consider a day-to-day activity. We leave our house on a two-wheeler, go to the railway station, park our vehicle board the train to our destination, reach the destination and attend the college/office.. here, the system that works for the solution to a problem in this case is expected to recognize certain ground conditions such as.

→ There is fuel in the two wheeler.

→ 2-wheeler is in a good condition.

→ There is no blockade during your travel.

→ Trains arrive puntually.

→ Train journey is safe etc.

In fact, it is not possible to consider all qualification that needs to be included. To minimise time & solution space, we make certain explicit assumptions that if there is something that is not mentioned, it need not be taken into consideration. So, for the above problem one need not bother about the factors discussed.

Practically, it corresponds to minimization of objects under consideration. In short in any problem, one considers only those whose existence is required for getting the clear picture of the solution. This principle of avoiding all unnecessary details and taking into account only those that are absolutely essential is called circumscription.

Probability-based reasoning:-

Belief revision takes place whenever one encounters a piece of information that decreases the beliefs on the fact. The source for all the uncertainities is the real world.

The following constitute the major chunk of uncertainities

→ Most information is not obtained personally but got from sources on which one has a lot of belief. Uncertainty prevails when the source does not send information in time or the information provided is not understood.

→ In laboratory experiments, one takes it for granted that the equipment is properly calibrated and error free. if the equipment is faulty, the picture one gets about the situation is not correct which leads to uncertainty.

→ Experimental errors like parallax errors are also sources of uncertainty

→ Imprecision in natural language is also a source for uncertainty. This is well exhibited in situations when the user speaks something and the listner understands something.

→ A random event occuring is a major source for uncertainty. To illustrate, a spike in the voltage might trigger a false alarm and the human operator is uncertain of the exact cause for the alarm.

→ In judicial courts we would have seen or heard delivering judgements acquitting the accused for

1. Lack of evidence.
2. Lack of certainty thereby giving the benefit of doubt to the accused.

To handle uncertain data, probability is the oldest technique Most events are dependent upon the one another. For these Bayes theorem is used for the computation of probabilities

BASIC PROBABILITY NOTATION:-

Any notation for describing degrees of beliefs must be able to deal with two main issues - the nature of sentences to which degree of beliefs are assigned and the dependence of the degree of belief on the agent's experience.

Propositions:-

Degrees of belief are always applied to propositions - assertions that such and such is the case.

we have two formal languages.

1 Propositional logic

2 first-order-logic - for stating propositions.

DOMAIN - Each random variable has a domain of values that it can take on. For example the domain of winning a race might be (true, false).

RANDOM VARIABLE:-

The basic element of the language is the random variable, which can be thought of as referring to a "part" of the world whose "status" is initially unknown.

Types of Random variables:-

↳ Boolean Random Variables:- such as Result, have the domain (true, false). often we will abbreviate a proposition such as Result = true simply by the lowercase name Result. Similarly ~~Cavity=false~~ Result = false would be abbreviated by ¬Result

↳ Discrete Random variables:-

It includes Boolean random variables as a special case, take on values from a Countable domain.

For example:- the domain of whether might be (sunny, rainy, cloudy, snow) The values in the domain must be mutually exclusive and exhaustive. where no confusion arises, we will use, for example, snow an abbrevation for ~~the~~ weather = snow.

3. continuous Random variables - Take on values from the real numbers. The domain can be either the entire real line or some subset such as the interval [0,1) For example, the proposition $X = 4.02$ asserts that the random variable X has the exact value 4.02 Propositions concerning continuous random variables can also be inequalities, such as $X \leq 4.02$.

Atomic events :-

The notion of an atomic event is useful in understanding the foundations of probability theory. An atomic event is a complete specification of the state of the world about which the agent is uncertain. It can be thought of as an assignment of particular values to all the variables of which the world is composed.

For example, if my world consists of only the Boolean variables cavity and toothache, then there are just four distinct atomic events, the proposition cavity = false $\wedge$ toothache = true is one such event.

Atomic events are some important properties :-

- They are mutually exclusive - at most one can actually be the case. for eg, cavity $\wedge$ toothache and cavity $\wedge \neg$ toothache cannot both be the case.
- The set of all possible atomic events is exhaustive - at least one must be the case. That is, the disjunction of all atomic events is logically equivalent to true.
- Any particular atomic event entails the truth or falsehood of every proposition, whether simple or complex. for eg, cavity $\wedge \neg$ toothache is equivalent disjunction of the atomic events cavity $\wedge$ toothache & cavity $\wedge \neg$ toothache.
- Any proposition is logically equivalent to the disjunction of all atomic events that entail the truth of the proposition. For eg, the proposition cavity is equivalent to disjunction of atomic events cavity $\wedge$ toothache. or cavity $\wedge \neg$ toothache

BAYES THEOREM-

This theorem provides a method of reasoning about partial beliefs. Here every event that is happening or likely to happen is quantified by pieces of knowledge about the event and the rules of probability dictate how these numerical values are to be calculated.

Let S stand for the statement "The horse challenger with jockey bhaskar will win the ooty race this season".

One can associate with this statement two probability values

→1. Probability of challenger winning the race Probability (challenger-winning) = 60%. This probability is called prior probability because we donot know the ground situation as on today.

→2. once we have a knowledge about the jockey bhaskar, the ground conditions and the other relevant information, the probability value might be revised. This probability value is called posterior probability, i.e.

Probability (challenger-winning / Jockey is Baskar) = 65%.

when there is a change in the belief about the condition of the horse, the jockey or the ground condition, probability values are also revised.

To explain Bayes theorem and its implications, consider the following example.

Assume that a person is a quality control expert in a factory that manufactures a hydraulic-based grooving machine. During the production and quality control tests let's assume that the following three faults are occurring in majority of the system and the symptoms for these are also given.

Fault	Likely Symptoms
1. Aeration	1 Noise 2. Air bubble in the noise tar-k.
3. Cavitation	1. Noise 3. Suction pressure of the pump less than 5" Mercury vaccum.
3. cartridge kit of pump damaged	1. Noise 2. Pump not developing pressure 3. Pump hot.

The symptom noise can be seen as common for all three defects. It is also possible to provide prior probabilities of the three defects as:-

Probability (Aeration) = Prob(Ar)

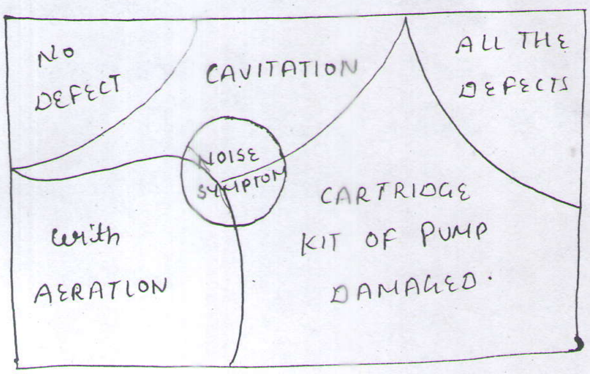
Probability (cavitation) = Prob(cav

Probability (cartridge damaged) = Prob (cart-damage)

Since the symptom noise is available for all the three ~~objects~~ defects, one can give a probability value of what is the probability of the aeration given the sympton noise. i.e.

Prob(Aeration/Noise)

The quality control person can test all the machines that are made to identify the machines with the defects. Upon testing, he might stumble upon a fig.



Distribution of faults

Since the defination of probability states that it is ratio of the number of occurences in favour to the total number of trials, we have the prior & posterior probability as
→ Prior ←

$$\text{Probability (Aeration)} = \frac{\text{Size of (Aeration)}}{\text{Size of (Total equipment manufactured)}}$$

$$\text{Probability (Noise)} = \frac{\text{Size of (Noise)}}{\text{Size of (Total equipment manufactured)}}$$

← Posterior →

$$\text{Probability (Aeration | NOISE)} = \frac{\text{Size of (Aeration AND Noise)}}{\text{Size of (Aeration)}}$$

$$\text{Probability (Noise / Aeration)} = \frac{\text{Size of (Aeration AND Noise)}}{\text{Size of (Noise)}}$$

The Bayesian probability, as stated before, follows the basic axioms of probability theory as-

1. Probability of statement is always greater than zero and less than unity.
2. The probability of sure proposition is unity.
3. Prob (A or B) = Prob (A) + Prob (B), if A & B are mutually exclusive.
4. Prob (NOT A) = 1 - Prob (A)

Bayes theorem of probability states that

$$\text{Prob (defect 1 | symptom 1)} = \frac{\text{Prob (defect 1)} * \text{Prob (symptom 1 | defect 1)}}{\text{Prob (symptom 1)}}$$

Prob (defect 1 | symptom 1) = Prob (Aeration | Noise)

Prob (defect 1) = Prob (Aeration)

Prob (symptom | defect 1) = Prob (Noise | Aeration)

THE AXIOMS OF PROBABILITY:-

Some basic axioms that serve to define the probability scale and its endpoints.

1. All proabilities between 0 and 1, for any proportional a,

$$0 \leq P(a) \leq 1$$

2. Necessarily true (i.e. valid) proportions have probability 1 & necessarily false (i.e. unsatisfisable) proportions have probability 0.

$$P(true) = 1 \qquad P(false) = 0.$$

3. The probability of a disjunction is given by

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

BAYE'S RULE & ITS USE:-

Probability can be written in two forms because of the communivity of conjunction.

$$P(a \wedge b) = P(a/b)\,P(b)$$

$$P(a \wedge b) = P(b/a)\,P(a).$$

Equating the two right hand sides & dividing by P(a) -

$$P(b/a) = \frac{P(a/b)\,P(b)}{P(a)}$$

The more general case of multivalued variables can be -

$$P(Y/X) = \frac{P(X/Y)\,P(Y)}{P(X)}$$

we will also have occasion to use a more general version conditionalized on some background evidence e:

$$P(Y/X,e) = \frac{P(X/Y,e)\,P(Y/e)}{P(X/e)}$$

Dempster-Shafer Theory

The Dempster-Shafer theory is designed to deal with the distinction between uncertainty and ignorance. Rather than computing the probability of a proposition, it computes the probability that evidence supports the proposition. This measure of belief is called a belief function, written Bel(X).

Example: We return to coin flipping for an example of belief functions. Suppose a shaddy character up to you and offers to bet you $10 that this coin will come up heads on the next flip. Given that the coin might or might not be fair, what belief should you ascribe to the event that it comes up heads? Dempster-Shafer theory says that because you have no evidence either way, you have to say that the Belief Bel(Heads) = 0 and also Bel(¬Heads) = 0.

Now suppose you have an expert at your disposal who testifies with 90% certainty that the coin is fair (i.e, he is 90% sure that P(Heads) = 0.5). Then Dempster Shafer theory gives Bel(Heads) = 0.9 × 0.5 = 0.45 and likewise Bel (¬Heads) = 0.45. There is still a 10 percent gap" that is not accounted for by the evidence. "Dempster's rule" shows how to combine evidence to give new values for Bel, and Shafer's work extend this into a complete computational model with probabilities, decision theory says that if P(Heads) = P(¬Heads) = 0.5, then (assuming that winning $10 and losing $10 are considered equal magnitude opposites) the reasoner will be indifferent between the action of accepting and declining the bet.

There is some information that probability cannot describe. For example ignorance. One interpretation of Dempster-Shafer theory is that it defines a probability interval:

[Belief, plausibility]

in which degree of belief must lie.

Belief measures the strength of the evidence in favor of a set of propositions. It ranges from 0 (indicating no evidence) to 1 (denoting certainty).

Plausibility is defined to be

$$Pl(s) = 1 - Bel(\neg s)$$

It also ranges from 0 to 1 and measures the extent to which in favor of $\neg s$ leaves room for belief in s.

So, In above example the probability interval for Heads is [0,1] before our expert testimony and [0.45, 0.55] after.

The Belief-plausibility interval we have just defined measures not only our level of belief in some propositions, but also the amount of information we have. Suppose that we are currently considering three competing hypothesis: A, B and C. If we have no information, we represent that by saying, for each of them, that the true likelihood is in the range [0,1]. As evidence is accumulated, this interval can be expected to shrink, representing increased confidence that we know how likely each hypothesis is. There is no clear meaning for what the width of an interval means. In the Bayesian approach, this kind of reasoning can be done easily by examining how much one's belief would change if one were to acquire more evidence.

Truth Maintenance System

A Truth maintenance system, or TMS is a knowledge representation method for representing both beliefs and their dependencies. The name truth maintenance is due to the ability of these systems to restore consistency.

A TMS satisfies a no. of goals.

1. Provide justifications for conclusion

When a problem solving system gives an answer to a user's query, an explanation of the answer is usually required. if the advice to a stockbroker is to invest millions of dollars, an explanation of the reasons for that advice can help the broker to reach a reasonable decision.

An explanation can be constructed by the Inference Engine by tracing the justification of the assertion.

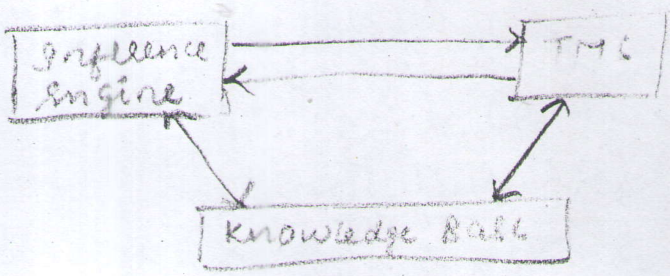
2. Recognise Inconsistencies

3. Support Default Reasoning

4. Support Dependency Driven backtracking → provides the natural indication of what assumptions need to be changed if we want to invalidate that sentence

Explanation of TMS

A Truth maintenance system maintains consistency b/w old believed knowledge and current believed knowledge in the knowledge base through revision. if the current believed knowledge contradict with the knowledge in KB then the KB is updated with the new knowledge. It may happen that the same data will again come into existence, therefore previous knowledge will be required in KB. if the previous data is not present, it is required for new inference. But if the previous knowledge was with KB, then no retracing of the same knowledge was needed. Hence the use of TMS to avoid such retracing; it keeps track of the contradictory data with the help of a dependency record



A TMS maintains a Dependency Network, with nodes representing sentences and justifications.

Premise: A sentence node is a ~~contradiction~~ premise if its sentence is true.

Contradiction: A sentence node is a contradiction if its sentence is false.

Assumption: A sentence node is an assumption if its sentence is assumed true or assumed false or assumed.

A sentence node receives arcs from justification nodes. Each such justification node provides an argument for believing the given sentence node. In turn a sentence node has arcs to the justification nodes that use it as a premise.

A justification node has inputs from sentence nodes, its premises or justifies and has output to a sentence node, its conclusion or justification. A justification node represents the inference of the conclusion from the conjuction of the stated premises.

TMS maintains the following information with each sentence node →

- a sentence

- a label expressing the current belief in the sentence.
- a list of the justification nodes that support it.
- a list of the justification nodes supported by it.
- an indication if the node is an assumption, contradiction or premise.

Justification-Based Truth Maintenance System (JTMS)

→ Simple TMS, does not know anything about the structure of the assertions themselves.

→ Each assertion in it has a justification

→ Each justification has two parts:

i> An IN-List: which supports beliefs held.

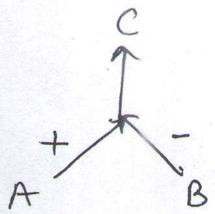
ii> An OUT-list: which supports beliefs not held

→ An assertion is connected to its justification by an arrow.

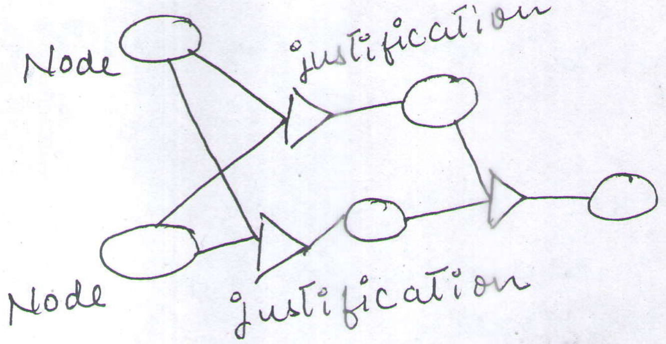
→ One assertion can feed another thus creating the network.

→ An Assertion is valid if every assertion in the IN-List is believed and none in the OUT-List are believed.

e.g.



According to this rule C is "in" if A is "in" & B is "out"



Logic-Based Truth Maintenance Systems (LTMS) ideal for real time propositional reasoning

→ Nodes assume no relationships among them except ones explicitly stated in justification

→ JTMS can represent (P) and (not P) simultaneously. An LTMS will throw contradiction here.

→ If this happens network has to be reconstructed.

Assumption-based Truth Maintenance Systems (ATMS)

→ JTMS & LTMS pursue a single line of reasoning at a time and backtrack when needed - depth first search

→ ATMS maintain alternative path in parallel - breadth first search

→ Backtracking is avoided at the expense of maintaining multiple contexts.

→ However As reasoning proceeds, contradictions arise and the ATMS can be pruned.

→ ATMS simply find assertion with no justification.

ATMS Data structures are →

Assumption, Environments, labels.

Two Major Types of TMS → 1. Single Context Systems
2. Multi-Context Systems

1.st - Consistency is maintained among all facts in memory.

2nd Allow consistency to be relevant to a subset of facts in memory.

Conclusion: Truth Maintenance Systems are significant as a mechanism for implementing dependency directed backtracking during search.