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AIML

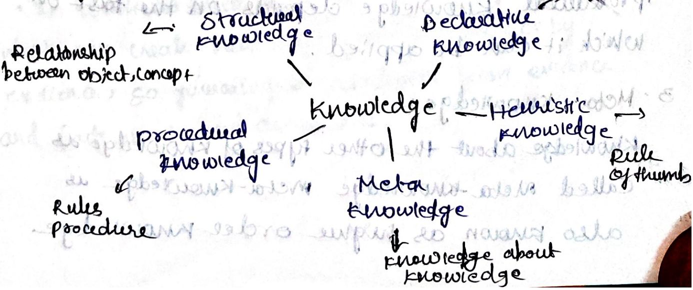
ASSIGNMENT-2

1) What is knowledge? Explain its types?

Knowledge is a familiarity, awarness, or understanding of someone or something that is acquired through experience or education. Knowledge of facts, also called propositional knowledge, is often characterized as true belief that is distinct from opinion or guesswork by virtue of justification.

Knowledge can be produced in many ways. The main source of empirical knowledge is perception, which involves the usage of the senses to learn about the external world. The main discipline investigating knowledge is epistemology, which studies what people know, how they come to know it, and what it means to know something.

Following are the types of knowledge in artificial intelligence:



1. Declarative Knowledge:-

Declarative knowledge which can be also understood as propositional knowledge, refers to static information and facts that are specific to a given topic, which can be easily accessed and retrieved. It's a type of knowledge where the individual is consciously aware of their understanding of the subject matter.

2. Procedural Knowledge:-

Procedural knowledge focuses on the 'how' behind which things operate, and is demonstrated through one's ability to do something. Where declarative knowledge focuses more on the 'who, what, where or when'; procedural knowledge is less articulated and shown through action or documented through manuals. It is also known as imperative knowledge. It includes rules, strategies, procedures, agendas etc. Procedural knowledge depends on the task on which it can be applied.

3. Meta-knowledge:-

Knowledge about the other types of knowledge is called Meta-knowledge. Meta-knowledge is also known as higher order knowledge.

Meta-knowledge is a fundamental conceptual instrument in such research and scientific domains as, knowledge engineering, knowledge management, and other dealing with study and operations on knowledge, seen as a unified object /entities, abstracted from local conceptualizations and terminologies.

4. Heuristic knowledge:-

- Heuristic knowledge is representing knowledge of some experts in a filed or subject.

5. Structural knowledge:-

Structural knowledge is basic knowledge to problem-solving. It describes relationships between various concepts such as kind of, part of, and grouping of something.

Q2) Explain inference rules in proposition logic and first order predicate logic.

Inference rules in proposition logic

Inference:-

- In artificial intelligence, we need intelligent computers which can create new logic from old logic or by evidence, so generating the conclusions from evidence and facts is termed as inference.

Inference rules:-

Inference rules are the templates for generating valid arguments. In Inference rules, the implication among all the connectives plays an important role.

rules :-

1. Modus ponens :-

The Modus ponens rule is one of the most important rules of inference, and it states that if p and $p \rightarrow Q$ is true, then we can infer that Q will be true.

It can be represented as:

Notation for Modus ponens: $\frac{p \rightarrow Q,\ p}{\therefore Q}$

ex:- $p \rightarrow Q$ (if it rains, the ground is wet)
p (It rains)
conclusion Q (The ground is wet)

2. Modus Tollens:- If $p \rightarrow Q$ is true and $\sim Q$ is true, then $\sim p$ will also be true. It can be represented as:

Notation for Modus Tollens: $\frac{P \rightarrow Q,\ \sim Q}{\sim P}$

ex:- $P \rightarrow Q$ (if it rains, the ground is wet)
$\sim Q$ (The ground is not wet)
Conclusion $\sim p$ (It didn't rain)

3. Hypothetical Syllogism:-

If $P \to R$ is true whenever $P \to Q$ is true, and $Q \to R$ is true

It can be represented as:

Ex:- Statement 1:- If you have my home key then you can unlock my home $P \to Q$

Statement 2:- If you unlock my home then you can take my money

$Q \to R$

Conclusion:- If you have my home key then you can take my money

$P \to R$.

4. Disjunctive syllogism:-

If $P \vee Q$ is true, and $\sim P$ is true, then Q will be true. It can be represented as:

Notation of Disjunctive syllogism: $\dfrac{P \vee Q, \sim P}{Q}$

Ex:- $P \vee Q$ (It's either raining or snowing)

$\sim P$ (It's not raining)

conclusion: Q (it's snowing)

5. Addition:-

If P is true, then $P \vee Q$ will be true

Notation of Addition: $\dfrac{P}{P \vee Q}$

6. Simplification

If $P \wedge Q$ is true, then Q or P will also be true

Notation of simplification rule: $\dfrac{P \wedge Q}{Q}$ or $\dfrac{P \vee Q}{P}$

7. Resolution:-

If $p \vee Q$ and $\sim p \wedge R$ is true, then $Q \vee R$ will also be true

Notation of Resolution $\dfrac{p \vee Q, \sim p \wedge R}{Q \vee R}$.

First-order-Logic

First-order logic another way of knowledge representation in AI. It is an extension to propositional logic.

First-order logic is also known as predicate logic or first order-predicate logic.

Inference in first order logic

1. Universal Instantiation (UI)

- If $\forall x\, p(x)$ ($p(x)$ is true for all x), then we can infer that $p(c)$ is true for any particular instance of c.

Ex:- $\forall x$ (x is human $\rightarrow x$ is mortal)

conclusion:- Socrates is a human $\rightarrow$ Socrates is mortal.

2. Existential Instantiation (EI)

If $\exists x\, p(x)$ (there exists some x such that $p(x)$ is true), we can instantiate an arbitrary constant c such that $p(c)$ is true

Ex:- $\exists x$ (x is a bird $\wedge$ x can fly)

conclusion:- Tweety is a bird $\wedge$ Tweety can fly.

3. Universal Generalization (UG)

If $P(c)$ is true for an arbitrary constant c, then $\forall x\, P(x)$ is true.

Ex:- For an arbitrary number c, $c+0=c$

conclusion: $\forall x (x+0=x)$

4. Existential ~~Generalizati~~ Introduction (EI)

This rule states that if there is some element c in the universe of discourse which has property P, then we can infer that there exists something in the universe which has the property P.

It can be represented as: $\dfrac{P(c)}{\exists x P(c)}$

Ex:-

Let's say that

Priyanka got good marks in english

Therefore, someone got good marks in English.

Q3) Explain types of quantifiers:

A quantifier is a language element which generates quantification, and quantification specifies the quantity of specimen in the universe of discourse.

There are two types of quantifier:

a. universal quantifier (for all, everyone, everything)

b. Existential quantifier (for some, at least one)

Universal quantifier:

Universal quantifier is a symbol of logical representation, which specifies that the statement within its range is true for everything or every instance of a particular thing.

The universal quantifier is represented by a symbol $\forall$, which resembles an inverted A.

We use implication $\rightarrow$

If x is a variable, then $\forall x$ is read as:

- for all x
- for each x
- for every x

Example:
All man drink coffee.

Let a variable x which refers to a cat so all x can be represented in UOD as below:

- x_1 drinks coffee
  $\wedge$
- x_2 drinks
  $\wedge$
- x_3 drinks milk
- ⋮
  $\wedge$
- x_n drinks milk.

$x_1, x_2, x_3, x_4, x_5, x_n$
Man

Universe of Discourse

So in shorthand notation, write as:

$\forall x \; man(x) \rightarrow drink(x, coffee).$

It will be read as: There are all x where x is a man who drinks coffee.

Existential Quantifier:

Existential quantifiers are the type of quantifiers, which express that the statement within its scope is true for at least one instance of something.

It is denoted by the logical operator ∃, which resembles as inverted E. When it is used with a predicate variable then it is called as an existential quantifier.

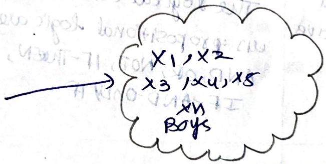
In existential quantifier we always use AND or conjunction symbol ($\wedge$)

- There exists a 'x'.
- for some 'x'.
- For at least one 'x'.

Example

Some boys are intelligent

- x_1 is intelligent
$\vee$
- x_2 is intelligent $\vee$
- x_3 is intelligent
$\vee$
⋮
$\vee$
- x_n is intelligent



Universe of Discourse

↓

So in short-hand notion, we write as:

$\exists x$: boys (x) $\wedge$ intelligent (x)

It will be read as: There are some x where x is a boy who is intelligent.

Q4) Write difference between proposition logic &
predicate logic

Basis	Propositional Logic	Predicate logic
Definition	Propositional logic consists of a declarative statement with a truth value, i.e. true or false, and can never be both simultaneously.	Predicate logic consists of a predicate that gives further information about a sentences subject. It can be referred to as an attribute that determines the properties of the subject in a sentence
Variables	propositional logic does not consists of variables	variables are present
Logical connectives	The logical connectives in propositional logic are AND, OR, NOT, IF-THEN, IF-AND-ONLY IF.	Logical connectives in predicate logic are the same as proposition logic and also contain propositional plus quantifiers
Scope analysis.	Scope analysis is not performed in propositional logic	Quantifiers are used to perform scope analysis in predicate-logic, such as universal quantifiers, existential quantifiers, Uniqueness quantifier etc.

Representation	propositional logic is a generalized representation	predicate logic is a specialized representation.
Truth value	In proposition logic, a proposition has a truth value i.e true or false	In predicate logic, the truth value depends on the value of variable
use case	propositional logic is used for analysing simple logical connections.	predicate logic is used for expressing complex connections and decisions for a given variable.

Q5) Explain FOL inference rules for quantifier:

As propositional logic we also have inference rules in first-order logic, so following are some basic inference rules in FOL:

- Universal Generalization
- Universal Instantiation
- Existential Instantiation
- Existential introduction.

Universal Generalization :-

Universal generalization is a valid inference rule which State that If premise $P(c)$ is true for any arbitary element c in the universe of discourse, then we can have a conclusion as $\forall x\ P(x)$.

It can be represented as :- $\dfrac{P(c)}{\forall x\ P(x)}$

Ex:- Let's represent, $P(c)$: "A byte contains 8 bits", so for $\forall x\ P(x)$ "All bytes contain 8 bits", it will also be true

Universal Instantiation :-

Universal Instantiation is also called as Universal elemination or UI is a valid inference rule. It can be applied multiple times to add new sentences.

The new KB is logically equivalent to the previous KB.

As per UI, we can infer any sentence obtained by Substituting a ground term of the variable.

It can be represented as :- $\dfrac{\forall x\ P(x)}{P(c)}$

Ex:- If "every person like ice-cream" $\Rightarrow \forall x\ P(x)$ so we can infer that "john likes ice-cream" $\Rightarrow P(c)$

Existential Instantiation:

Existential Instantiation is also called as Existential Elimination, It can be applied only one to replace the existential sentence.

The new KB is not logically equivalent to old KB, but it will be satisfiable if old KB was satisfiable

It can be represented as: $\frac{\exists x\, P(x)}{P(c)}$

Example

- From the given sentence: $\exists x$ Crown(x) $\wedge$ OnHead(x, john),
- So we can infer: Crown(K) $\wedge$ OnHead(K, john), as long as K does not appear in the knowledge base.
- The above used K is a constant symbol, which is called Skolem constant.
- The existential instantiation is a special case of Skolemization process.

Existential Introduction:

- An existential introduction is also known as an existential generalization, which is a valid inference rule in first-order logic
- This rule states that if there is some element c in the universe of discourse which has a property P, then we can infer that there exists something in the universe which has the property P.

It can be represented as: $\frac{P(c)}{\exists x\, P(x)}$

Example:
Let's say that
- "Priyanka got good marks in English".
- "Therefore, someone got good marks in english."

Q6) Explain resolution in First order logic.

- Resolution is a theorem providing technique that proceeds by building refutation proofs i.e., proofs by contradictions.
- Resolution is used, if there are various statements are given, and we need to prove a conclusion of those statements.
- Resolution is a single inference rule which can efficiently operate on the conjunctive normal form or clausal form.
- Conjunctive Normal Form: A sentence represented as a conjunction of clauses is said to be conjunctive normal form or CNF.

Note: An expression in CNF is a "product of sums".

Example:
a) Ravi likes all kind of food.
b) Apple and chicken are food.
c) Anything anyone eats and is not killed is Food.
d) Ajay eats peanuts and still alive.

prove! Ravi likes peanuts.

* likes (Ravi, peanuts)

write in FOL form

. likes (Ravi, peanuts) => ~ likes (Ravi, peanuts)

Steps to solve Resolution:-

1. Negate the statement to be proved
2. convert given facts into FOL
3. convert FOL into CNF
4. Draw resolution graph.

convert the facts into FOL

1. Ravi likes all kind of food.

   ∀x : food(x) -> likes (Ravi, x)

2. Apple and chicken are food

   i) Food(apple)

   ii) Food(chicken)

3. Anything anyone eats and is not killed is food.

   ∀x ∀y: eats (x, y) ∧ ~killed (x) -> food(y)

4. Ajay eats peanuts and still alive

   eats(ajay, peanuts) ∧ alive(ajay)

5. ∀x: ~killed (x) -> alive (x)

6. ∀x: alive (x) -> ~ killed (x)

added predicates

Convert FOL into CNF

1. eliminate '→' & '↔'

$a \rightarrow b : \sim a \vee b$

$a \leftrightarrow b : a \rightarrow b \wedge b \rightarrow a$

2. Move ~ inward.

- $\sim(\forall x P) = \exists x \sim P$
- $\sim(\exists x P) = \forall x \sim P$
- $\sim(a \vee b) = \sim a \wedge \sim b$
- $\sim(a \wedge b) = \sim a \vee \sim b$
- $\sim(\sim a) = a$

3. Rename variable

4. Replace existential quantifier by skolem constant

$\exists x \; Rich(x) = Rich(G1)$

5. Drop universal quantifier.

1. food(x) → likes(Ravi, x)

~food(x) ∨ likes(Ravi, x) [a→b = ~a ∨ b]

2. eats(x, y) ∧ ~killed(x) → food(y)

~[eats(x,y) ∧ ~killed(x)] ∨ food(y)

~eats(x,y) ∨ killed(x) ∨ food(y)

3. eats(ajay, peanuts) ∧ alive(ajay) (Pitch in resolution graph)

4. ~~killed(x) ∨ alive(x) : killed(x) ∨ alive(x)

5. ~alive(x) → ~~killed(x) : ~alive(x) ∨ killed(x)

Q7. Consider the following set of well-formed formulas in predocate logic:

Man (Marcus)
pompeian (Marcus)
∀ x: pompeian (x) → Roman (x)
Rulee (caesce)
∀ x: Raman (x) → loyalto (x, caeseer) ∨ hate (x, caesar)
∀x: y loyalto(x,y)
∀ x : ∀ y Man(x) ∧ tryassassinate (x, y) → loyalto(x,y)
Tryassasinate (Marcus, caesar)

convert these into clause Form and prove that hate (Marcus, caser) using resolution proof.

Step 1:- convert the formulas in to first-order predicate logic

1. Man(Marcus)
   - predicate: Marcus is a man.

2. pompeian (Marcus)
   - Marcus is a pompeian.

3. ∀x (pompeian (x) → Roman (x))
   - universal statement: All pompeians are Romans
   - In CNF: ~ pompeian (x) ∨ Roman(x)

4. Ruler (caesar)

predicate : caesar is a ruller

5. $\forall x$ (Roman(x) $\rightarrow$ loyalto (x, caesar) V hate(x, caesar))

• Universal statement: All Romans are either Loyal to caesar or they hate caesar

• IN CNF: ~Roman (x) V loyalto (x, caesar) V hate (x, caesar)

6. $\forall x$ $\forall y$ (loyalto (x, y))

• This appears to be an incomplete formula. If it means "for all x and y, Loyalto (x, y) is true," it implies everyone is loyal to everyone, which might be a mistake. well skip this for now.

7. $\forall x$ $\forall y$ (Man (x) $\wedge$ tryassassinate (x, y) $\rightarrow$ loyalto (x, y))

• if a man tries to assassinate someone, he is loyal to that person

• IN CNF: ~Man (x) V ~tryassassinate (x, y) V loyalto(x, y)

8. Tryassassinate (Marcus, caesar)

• Predicate: Marcus tries to assassinate caesar.

Step2: convert each formula into CNF

(1) Man (Marcus)

Already in CNF : Man (Marcus)

(2) pompeian(Marcus)

Already in CNF ! pompeian(Marcus)

(3) ∀x(pompeian(x) → Roman(x)) This becomes ~pompeian(x) V Roman(x), and with the substitution x = Marcus, it becomes:

~pompeian(Marcus) V Roman(Marcus)

(4) Ruler(caesar)

(5) ∀x (Roman(x) → loyalto(x, caesar) V hate(x, caesar)) :

This becomes ~Roman(x) V loyalto(x, caesar) V hate(x, caesar)

~Roman(Marcus) V loyalto(Marcus, caesar) V hate(Marcus, caesar)

(6) skipping the unclear formula ∀x ∀y loyalto(x, y) as it doesn't seem relevant here.

(7) ∀x ∀y (Man(x) ∧ tryassassinate(x, y) → loyalto(x,y))

This becomes ~Man(x) V ~tryassassinate(x,y) V loyalto(x,y),

and with x = Marcus and y = Caesar :

~Man(Marcus) V ~tryassinate(Marcus, caesar) V loyalto(Marcus, caesar)

(8.) Tryassassinate(Marcus, caesar).

Step3: List the clauses.

1. Man(Marcus)
2. Pompeian(Marcus)
3. ~pompeian(Marcus) V Roman(Marcus)
4. ~Roman(Marcus) V loyalto(Marcus, caesar) V hate(Marcus, caesar)

5. ~Man(Marcus) V ~ Tryassassinate (Marcus, Caesar) V
Loyalto (Marcus, Caesar)

6. Tryassassinate (Marcus, Caesar).

Step 1:- Negate the goal and add it to the clauses
The goal is to prove hate (Marcus, Caesar). Negate it
and add ~~to~~ the clauses:

~ hate (Marcus, Caesar)

Step 5: Resolution proof:

1. from clause (4): ~ Roman(Marcus) V loyalto(Marcus, Caesar)
V hate(Marcus, Caesar)

2. from the negated goal: ~ hate (Marcus, Caesar)

By solving (1) and (2) we get:

- ~Roman(Marcus) V loyalto(Marcus, Caesar)

3. from clause (3): ~pompeian (Marcus) V Roman(Marcus)
4. from clause (2): pompeian (Marcus)

By solving (3) and (4) we get

- Roman (Marcus)

5. from the result of step (1) and the result of step (4):
~ Roman (Marcus) V loyalto(Marcus, Caesar) and Roman (Marcus)

By solving these, we get,

- Loyalto(Marcus, Caesar)

6. from clause (5): ~~#~~ ~ Man (Marcus) V ~Tryassassinate
(Marcus, Caesar) V loyalto (Marcus, Caesar)

7. From clause (6):

Try assassinate (Marcus, caesar)

8. From clause (1): Man(Marcus)

By solving (6), (7) and (8), we get:

. loyalto (Marcus, caesar)

since we have derived loyalto (Marcus, caesar), but this contradicts the negated goal that we need to prove hate (Marcus, caesar) (we can't have both loyalto (Marcus, caesar) and hate (Marcus, caesar)), we reach a contradiction.

Step 6: Conclusion

By resolving the clauses, we derive a contradiction, proving that hate (Marcus, caesar) must be true. Thus, hate (Marcus, caesar) is proven using resolution proof.

Q8) use the inference rules to derive the soundness of the argument derivation the reason for the ~~number~~ murder.

P: Robbery was the reason for the murder

Q: Something was taken.

R: politics was the reason for the murder

S: A woman was the reason for the murder

T: The murderer left immediately.

U: The murderer left tracks all over the room.

FOPL Representation:

we can express the relationships between these propositions using implication statements:

1. $P \rightarrow Q$: If robbery was the reason for the murder, then Something was taken
   - FOPL: $\forall x(P(x) \rightarrow Q(x))$
2. $R \rightarrow T$: If politics was the reason for the murder then the murderer left immediately
   - FOPL: $\forall x(R(x) \rightarrow T(x))$
3. $S \rightarrow U$: If a woman was the reason for the murder, then the murderer left tracks all over the room.
   - FOPL: $\forall x(S(x) \rightarrow U(x))$

Given Observations (Assumptions):

- $\sim Q$: something was not taken
  - FOPL: $\sim Q(x)$
- $\sim T$: The murderer did not leave immediately
  - FOPL: $\sim T(x)$
- U: The murderer left tracks all over the room
  - FOPL: $U(x)$

Logical Reasoning:

Let's use the above observations to deduce the cause of the murder.

1. Analyze $P \rightarrow Q$ and $\sim Q$:
   - premise: $P \rightarrow Q$ (if robbery was the reason, Something was taken).

• Observation : $\sim Q$ (something was not taken).

Modus Tollens :

• Since Q is false ($\sim Q$), P must be false ($\sim P$).

• Conclusion : Robbery was not the reason for the murder.

2. Analyze $R \rightarrow T$ and $\sim T$:

• Premise: $R \rightarrow T$ (if politics was the reason, the murderer left immediately)

• Observation: $\sim T$ (The murderer did not leave immediately).

Modus Tollens:

• Since T is false ($\sim T$), R must be false ($\sim R$).

• Conclusion: Politics was not the reason for the murder

3. Analyze $S \rightarrow U$ and U:

• Premise : $S \rightarrow U$ (if a woman was the reason, the murderer left tracks all over the room).

• Observation : U (The murderer left tracks all over the room).

Modus ponens:

• Since U is true and $S \rightarrow U$ holds, S must be true

• Conclusion: A woman was the reason for the murder

Final conclusion:-

Based on the logical derivation using the given premises and observations :

• Robbery was not the reason for the murder ($\sim P$).

• Politics was not the reason for the murder ($\sim R$).

• A woman was the reason for the murder (S).

Q9) Define Bayes theorem with an example.

· Bayes theorem is also known as Bayes' rule, Bayes' law or Bayesian reasoning, which determines the probability of an event with uncertain knowledge.

formula for Bayes' Theorem.

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

where
→ $P(A|B)$ – the probability of event A occuring, given event B has occured
→ $P(B|A)$ – the probability of event B occuring, given event A has occurred.
→ $P(A)$ – the probability of event A
→ $P(B)$ – The probability of event B.

→ $P(B|A)$ is known as posterior, which we need to calculate, and it will be read as probability of hypothesis A when we have occured an evidence B.
→ $P(B|A)$ is called the likelihood, in which we consider that hypothesis is true, then we calculate the probability of evidence.
→ $P(A)$ is called the prior probability, probability of hypothesis before considering the evidence.

→ P(B) is called Marginal probability, pure probability of an evidence.

$$P(cause \mid effect) = \frac{P(effect \mid cause)\, P(cause)}{P(effect)}$$

example:- What is the probability that a person has lung cancer given that they are experiencing a persistent cough?

Given Data:

- A doctor is aware that lung cancer causes a patient to have a persistent cough, and it occurs 70% of the time.
- The known probability that a patient has lung cancer is 1 in 10,000.
- The known probability that a patient has a persistent cough is 5%.

Let:

- a is be the proposition that the patient has a persistent cough.
- b be the proposition that the patient has lung cancer.

Thus, we have the following information:

- $p(a \mid b) = 0.7$ (The probability of having a persistent cough given that the person has lung cancer).
- $p(b) = 1/10000 = 0.0001$ (The probability of having lung cancer).
- $p(b) = 0.05$ (The probability of having a persistent cough).

- Now, we can calculate the probability that a person has lung cancer given that they have a persistent cough using Bayes' Theorem:

$$p(b|a) = \frac{P(a|b) \cdot P(b)}{P(a)}$$

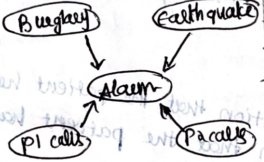
$$p(b|a) = \frac{0.7 * 0.0001}{0.05} = \frac{0.00007}{0.05} = 0.0014$$

- So the probability that a person has lung cance given that they have a persistent cough is 0.0014 or 0.14 %.

Q10. Explain Bayesian belief network with the example

List of all event occuring in this network:

- Burglary (B)
- Earthquake (E)
- Alarm (A)
- P1 calls (P1)
- P2 calls (P2)



B	E	P(A=T)	P(A=F)
T	T	0.95	0.05
T	F	0.94	0.06
F	T	0.29	0.71
F	F	0.001	0.999

Alarm (A)	P(P1=T)	P(P1=F)
T	0.90	0.10
F	0.05	0.95

Alarm (A)	P(P2=T)	P(P2=F)
T	0.70	0.30
F	0.01	0.99

- $P(B=T) = 0.001$
- $P(B=F) = 0.999$
- $P(E=T) = 0.002$
- $P(E=F) = 0.998$

- Calculate the probability that alarm has sounded, but there is neither a burglary, nor an earthquake occured, and P1 and P2 both called the x.

Ans The problem asks to calculate the probability that the alarm has sounded, but there was neither a burglary nor an earthquake, and both p1 and p2 called (denoted as x).

To solve this, we use the given probabilities from the image and apply the conditional probability formula using the bayesian network.

Variables:
- B: Burglary
- E: Earthquake
- A: Alarm
- p1: p1 calls
- p2 calls

conditions
- No Burglary $B=F$
- No earthquake $E=F$
- Alarm sounded $A=T$
- p1 called $p1=T$
- p2 called $p2=T$

Step by step solution:

1. Alarm probability $P(A=T \mid B=F, E=F)$: According to the given table for $P(A=T)$ with $B=F$ and $E=F$:
$$P(A=T \mid B=F, E=F) = 0.001$$

2. p1 calling Given Alarm $P(p1=T \mid A=T)$: from the table, for $A=T$:
$$P(p1=T \mid A=T) = 0.90$$

3. p2 calling Given Alarm $P(p2=T \mid A=T)$ from the table, for $A=T$:
$$P(p2=T \mid A=T) = 0.70.$$

4. Joint probability calculation: The joint probability of all these events occurring together is the product of their individual probabilities:

$P(B=F, E=F, A=T, P1=T, P2=T) = P(A=T \mid B=F, E=F) \times P(P1=T \mid A=T) \times P(P2=T \mid A=T)$

Substituting the values:

$P(B=F, E=F, A=T, P1=T, P2=T) = 0.001 \times 0.90 \times 0.70$

$P(B=F, E=F, A=T, P1=T, P2=T) = 0.00063$

So, the probability that the alarm sounded, but there was neither a burglary nor an earthquake, and both P1 and P2 called is 0.00063.