**Intelligent Systems**

**Assignment 09. KBAs using   
 Propositional Logic**



# Exercise description

This assignment will implement the topics covered on Knowledge-Based Agents using Propositional Logic.

**Team members**

Write the student id, name, and campus of each member in a different line.

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**Assignment**

**1. Define a vocabulary of positive propositions and formalize the following statements:**

**a. If the rain continues, then the river will flood.**

Vocabulary:

S: The rain continues

P: The river will flood

Translation:

S -> P

**b. Alice is not married but Bob is not single.**

Vocabulary:

S: Alice is married

P: Bob is single

Translation:

~S ^ ~P

**c. I will go to the party unless Rufus is there.**

Vocabulary:

S: I will go to the party

P: Rufus is in the party

Translation:

P -> S

**d. Being a cat is a sufficient condition of being a mammal.**

Vocabulary:

S: Being a cat

P: Being a mammal

Translation:

S -> P

**e. Only if Jenna passes the exam will Jenna get her license.**

Vocabulary:

S: Jenna passes the exam

P: Jenna gets her license

Translation:

S -> P

**f. I do not like peanut butter and I do not like jelly.**

Vocabulary:

S: I like Peanut butter

P: I like Jelly

Translation:

~S ^ ~P

**g. It is not the case that Tom and Dick will work late or that Harry will call in sick.**

Vocabulary:

S: Tom will work late

P: Dick will work late

R: Harry will call in sick

Translation:

~((S ^ P) V R)

**2. Use the truth table method to verify whether the next logical consequence is correct:**

**a. {p ∨ q} |= p → q**

The logical consequence is not correct.

|  |  |  |  |
| --- | --- | --- | --- |
| **P** | **Q** | **P v Q** | **P -> Q** |
| 1 | 1 | 1 | 1 |
| 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 1 |

**b. {p → q, ¬r → ¬q} |= p → r**

The logical consequence is correct

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **P** | **Q** | **R** | **P -> Q** | **~R** | **~Q** | **~R -> ~Q** | **P -> R** |
| 1 | 1 | 1 | **1** | 0 | 0 | **1** | **1** |
| 1 | 1 | 0 | **1** | 1 | 0 | **0** | **0** |
| 1 | 0 | 1 | **0** | 0 | 1 | **1** | **1** |
| 1 | 0 | 0 | **0** | 1 | 1 | **1** | **0** |
| 0 | 1 | 1 | **1** | 0 | 0 | **1** | **1** |
| 0 | 1 | 0 | **1** | 1 | 0 | **0** | **1** |
| 0 | 0 | 1 | **1** | 0 | 1 | **1** | **1** |
| 0 | 0 | 0 | **1** | 1 | 1 | **1** | **1** |

**3. Use the truth table method to verify whether the following formulas are valid (a tautology), satisfiable, or unsatisfiable (a contradiction):**

**a. ¬ (p <-> ¬q → r)**

Satisfiable

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **p** | **q** | **r** | **~q** | **p <-> ~q** | **(p <-> ~q) -> r** | **~((p <-> ~q) -> r)** |
| 1 | 1 | 1 | 0 | 0 | 1 | **0** |
| 1 | 1 | 0 | 0 | 0 | 1 | **0** |
| 1 | 0 | 1 | 1 | 1 | 1 | **0** |
| 1 | 0 | 0 | 1 | 1 | 0 | **1** |
| 0 | 1 | 1 | 0 | 1 | 1 | **0** |
| 0 | 1 | 0 | 0 | 1 | 0 | **1** |
| 0 | 0 | 1 | 1 | 0 | 1 | **0** |
| 0 | 0 | 0 | 1 | 0 | 1 | **0** |

**b. (p → r V s) Λ (r → s) Λ ¬ (p → s)**

Satisfiable

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **p** | **r** | **s** | **r v s** | **p -> r v s** | **r -> s** | **p -> s** | **(p → r V s) Λ (r → s) Λ ¬ (p → s)** |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | **1** |
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | **0** |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | **1** |
| 1 | 0 | 0 | 0 | 0 | 1 | 0 | **0** |
| 0 | 1 | 1 | 1 | 1 | 0 | 1 | **0** |
| 0 | 1 | 0 | 1 | 1 | 1 | 1 | **1** |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | **1** |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | **1** |

**4. Reduce the following formula to its clausal form:**

**a. ¬ (p ↔ ¬q → r)**

1. Remove implications and biconditionals

~((p -> ~q) ^ (~q -> p)) ->r

~((~p v ~q) ^ (~~q v p)) -> r

~~((~p v ~q) ^ (~~q v p)) v r

2. Introduce negations

((~p v ~q) ^ (q v p)) v r

3. Distribute disjunctions over conjunctions

((~p v ~q) v r) ^ ((q v p) v r)

4. Clauses:

C1: ~p v ~q v r

C2: q v p v r

**b. (p → r V s) Λ (r → s) Λ ¬ (p → s)**

1. Remove implications and biconditionals

(~p v (r v s)) ^ (~r v s) ^ ~(~p v s)

2. Introduce negations

(~p v r v s) ^ (~r v s) ^ (p ^ s)

3. Distribute disjunctions over conjunctions

None

4. Clauses:

C1: ~p v r v s

C2: ~r v s

C3: p

C4: s

**5. Ash, Misty and Brock have organized a battle between their Pokémon. The following data are known in this regard:**

a) One, and only one, of the following Pokemon was the winner: Pikachu, Bulbasaur, Togepi, Starmie, Vulpix and Onix.

b) Ash won the battle if the winning Pokemon was Pikachu or Bulbasaur.

c) If either Togepi or Starmie was the winner, Misty won the battle.

d) Brock won the battle if the winner was Onix or Vulpix.

e) If Onix was defeated, Starmie too.

f) Bulbasaur was defeated.

g) If Pikachu was defeated, then Ash did not win the battle.

h) Brock did not win the battle if Bulbasaur was defeated.

i) If Vulpix was defeated, Togepi and Onix also suffered the same fate.

**You are asked to:**

1. **Formalize the previous data in the language of propositional logic.**

Vocabulary:

P: Pikachu was the winner

B: Bulbasaur was the winner

T: Togepi was the winner

S: Starmie was the winner

V: Vulpix was the winner

O: Onix was the winner

A: Ash won the battle

M: Misty won the battle

Br: Brock won the battle

Translation:

*a) P <-> ~(B v T v S v V v O) … and so on for every other combination*

b) A -> (P v B)

c) (T v S) -> M

d) Br -> (O v V)

e) ~O -> ~S

f) ~B

g) ~P -> ~A

h) ~Br -> ~B

i) ~V -> (~T ^ ~O)

**2. For each formula obtained, write an equivalent set of clauses in conjunctive normal form (CNF).**

b) ~A v P v B

c) ~(T v S) v M … (~T ^ ~S) v M …(~T v M) ^ (~S v M)…

c1) ~T v M

c2) ~S v M

d) ~Br v O v V

e) O v ~S

f) ~B

g) P v ~A

h) Br v ~B

i) P v ~A

3. Using resolution by refutation, prove that **Ash was the winner**.