Department Of Computer Science, CUI Lahore Campus

CSC102 - Discrete Structures

By

Muhammad Zuhair Qadir

Lecture Outline

- Propositional Logic
  - Proposition and Propositional Variables
  - Compound Proposition
  - Logical Operators
  - Truth Table of a compound proposition

Propositional Logic

- Proposition
  - A proposition is a declarative statement that is either TRUE or FALSE, but not both.

- Example 1
  - 2 + 5 = 4.
  - Lahore is the capital of Pakistan.
  - It is Monday today.
  - Ali is student of this class.

- Example 2
  - What time is it?
  - X + 1 = 2.
  - Close the door.
  - Read this carefully.

Propositional Logic

- Letter are used to denote propositional variables, to symbolically represent propositions.
  - Letters used for this purpose are p, q, r, s,………
  - A propositional can have one of two values: true (T) or false (F).
- Example
  - ***p* =** “Islamabad is the capital of Pakistan”
  - ***q* =** “17 is divisible by 3”

Propositional Logic

- The area of logic that deals with propositions is called the *Propositional Calculus* or *Propositional Logic.*

- *Compound Propositions* are constructed by combining one or more propositions using logical operators (connectives).

- Examples
    - “3 + 2 = 5” **and** “Lahore is a city in Pakistan”
    - “The grass is green” **or** “ It is hot today”

Symbols for Logical Operators

Symbol	Meaning
$\neg$	Negation
$\wedge$	And, Conjunction
$\vee$	Or, Disjunction
$\rightarrow$	Implication
$\leftrightarrow$	Bi-Conditional

Logical Operators (Logical connectives)

- Negation

  - This just turns a false proposition to true and the opposite for a true proposition.
  - Symbol: $\neg$
  - Let p is a proposition. The statement

    "It is not the case that p."

    is another proposition, called the negation of p.

  - The negation of p is written $\neg p$ and read as "not p".

Logical Operator - Negation

- Logical operators are defined by **truth table** – table which give the output of the operator in the right-most column.
- Here is the truth table for negation:

p	**¬p**
T	F
F	T

Logical Operator - Negation

- Example

  Let p = "Today is Friday."

  The negation of p is

  ¬p = "It is not the case that today is Friday."
  ¬p = "Today is not Friday."
  ¬p = "It is not Friday today."

- What is negation of following proposition: "My PC runs Linux"

Logical Operator - Conjunction

- Conjunction is a *binary* operator in that it operates on two propositions when creating compound proposition. On the other hand, negation is a *unary* operator.
- Conjunction corresponds to English "and."
- Symbol: $\wedge$
- Let p and q be propositions. The conjunction of p and q, denoted by $p \wedge q$, is the proposition "p and q". The conjunction $p \wedge q$ is true when both p and q are true. If one of these is false, than the compound statement is false as well.

Logical Operator - Conjunction

- Truth Table

p	q	p ∧ q
T	T	T
T	F	F
F	T	F
F	F	F

Logical Operator - Conjunction

- Example

Let p = “Today is Friday.”
and q = “It is raining today.”

$p \wedge q$ = “Today is Friday and it is raining today.”

Logical Operator - Conjunction

- Hamza’s PC has more than 16 GB free hard disk space, and the processor in Hamza’s PC runs faster than 1 GHz.

- It is cold but sunny.

Logical Operator - Disjunction

- Disjunction is also a binary operator.
- Disjunction corresponds to English “or.”
- Symbol: $\lor$

- Let p and q be propositions. The disjunction of p and q, denoted by $p \lor q$, is the proposition “p or q”. The conjunction $p \lor q$ is false when both p and q are false and is true otherwise.

Logical Operator - Disjunction

- Truth Table

p	q	p ∨ q
T	T	T
T	F	T
F	T	T
F	F	F

Logical Operator - Disjunction

- Example

Let p = “Today is Friday.”
and q = “It is raining today.”

$p \vee q$ = “Today is Friday or it is raining today.”

Example

Let p = “it is sunny”,

q = “it is raining”

- It is sunny and raining. $p \land q$
- It is not sunny but raining. $\neg p \land q$
- It is neither sunny nor raining. $\neg p \land \neg q$

Logical Operator – Exclusive Or

- Symbol: $\oplus$
- Let p and q be propositions. The exclusive or of p and q, denoted by $p \oplus q$, is the proposition that is true when exactly one of p and q is true and is false, and false otherwise.
- Truth Table

p	**q**	**$p \oplus q$**
T	T	F
T	F	T
F	T	T
F	F	F

Logical Operator – Exclusive Or

- Example

  Let p = "Students who have taken calculus can take this class."

  and q = "Students who have taken computer science can take this class."

  $p \vee q$ = "Students who have taken calculus or computer science can take this class."

  $p \oplus q$ = "Students who have taken calculus or computer science, but not both, can take this class."

Exclusive or Versus Inclusive or (Disjunction)

- Coffee or tea comes with dinner. — Exclusive or
- A password must have at least three digits or be at least five characters long. — Inclusive or
- Lunch includes soup or salad. — Exclusive or
- Experience with C++ or Java is required. — Inclusive or

Logical Operator – Implication

- $p \rightarrow q$ corresponds to English "if *p* then *q*," or "*p* implies *q*."
- Symbol: $\rightarrow$
- The implication p $\rightarrow$ q is the proposition that is false when p is true and q is false, and true otherwise.

$$p \rightarrow q$$

Hypothesis Conclusion

- Examples
  - If it is raining then it is cloudy.
  - If you get 100% on the final, then you will get an A.
  - If *p* then 2+2 = 4.

Logical Operator – Implication

- Truth Table

p	q	$p \rightarrow q$
T	T	T
T	F	F
F	T	T
F	F	T

Logical Operator – Implication

- Alternate ways of stating an implication
  - *p* implies *q*
  - If *p*, *q*
  - *p* only if *q*
  - *p* is sufficient for *q*
  - *q* if *p*
  - *q* whenever *p*
  - *q* is necessary for *p*

Implication - Example

p: you get 100% on the final
q: you will get an A

- **p implies q.**
  you get 100% on the final implies you will get an A.
- **If p, then q.**
  If you get 100% on the final, then you will get an A.
- **If p, q.**
  If you get 100% on the final, you will get an A.
- **p is sufficient for q.**
  Get 100% on the final is sufficient for getting an A.
- **q if p.**
  you will get an A if you get 100% on the final.
- **q unless $\neg$ p.**
  you will get an A unless you don't get 100% on final.

Logical Operator – Implication

- Converse

  The proposition $q \rightarrow p$ is **converse** of $p \rightarrow q$.

- Contrapositive

  The **contrapositive** of $p \rightarrow q$ is the proposition $\neg q \rightarrow \neg p$.

- Inverse

  The proposition $\neg p \rightarrow \neg q$ is called the **inverse** of $p \rightarrow q$.

Logical Operator – Implication

- Example

  "The home team wins whenever it is raining"

Because "q whenever p", so $p \rightarrow q$, the original statement can be rewritten as "If it is raining, then the home team wins."

- Contrapositive

  "If the home team does not win, then it is not raining."

- Converse

  "If the home team wins, then it is raining."

- Inverse

  "If it is not raining, then the home team does not win."

Logical Operator – Bi-conditional

- $p \leftrightarrow q$ corresponds to English "*p* if and only if *q*."
- Symbol: $\leftrightarrow$
- The bi-conditional statement $p \leftrightarrow q$ is true when *p* and *q* have the same truth values, and is false otherwise.
- Bi-conditional statements are also called *bi-implications*.
- Alternatively, it means "(if p then q) and (if q then p)"

- Example
  - "You can take the flight if and only if you buy a ticket."

Logical Operator – Bi-conditional

- Truth Table

p	q	$p \leftrightarrow q$
T	T	T
T	F	F
F	T	F
F	F	T

Logical Operator – Bi-conditional

p: You can take flight

q: You buy a ticket

$p \leftrightarrow q$

You can take flight if and only if you buy a ticket

What is the truth value when:

- you buy a ticket and you can take the flight ??
  $T \leftrightarrow T \equiv T$
- you don't buy a ticket and you can't take the flight ??
  $F \leftrightarrow F \equiv T$
- you buy a ticket but you can't take the flight ??
  $T \leftrightarrow F \equiv F$
- you can't buy a ticket but can take the flight ??
  $F \leftrightarrow T \equiv F$

Logical Operator – Bi-conditional

- Other English equivalents:
  - “p if and only if q”
  - “p is equivalent to q”
  - “p is necessary and sufficient for q”
  - “p iff q”
  - “If p then q, and conversely”

Bi-conditional -Example

p: “You can take the flight”

q: “You buy a ticket”

$p \leftrightarrow q$:

You can take the flight if and only if you buy a ticket

You can take the flight iff you buy a ticket

The fact that you can take the flight is necessary and sufficient for buying a ticket

Logical Operators Summary

		Not	Not	And	Or	Xor	Implication	Bi-conditional
p	**q**	$\neg$**p**	$\neg$**q**	**p** $\wedge$ **q**	**p** $\vee$ **q**	**p** $\oplus$ **q**	**p** $\rightarrow$ **q**	**p** $\leftrightarrow$ **q**
T	T	F	F	T	T	F	T	T
T	F	F	T	F	T	T	F	F
F	T	T	F	F	T	T	T	F
F	F	T	T	F	F	F	T	T

Truth Table of Compound Propositions

- Construction of a truth table:
- Rows
  - Need a row for every possible combination of values for the every propositions.
- Columns
  - Need a column for the compound proposition (usually at far right)
  - Need a column for the truth value of each expression that occurs in the compound proposition as it is built up.
  - This includes the atomic propositions

Truth Table of Compound Propositions

- $(p \vee \neg q) \rightarrow (p \wedge q)$

Truth Table of Compound Propositions

- $(p \vee \neg q) \rightarrow (p \wedge q)$

p	q	$\neg q$	$p \vee \neg q$	$p \wedge q$	$(p \vee \neg q) \rightarrow (p \wedge q)$
T	T	F	T	T	T
T	F	T	T	F	F
F	T	F	F	F	T
F	F	T	T	F	F

Truth Table of Compound Propositions

- $p \rightarrow (\neg q \wedge r)$

Truth Table of Compound Propositions

- $p \rightarrow (\neg q \wedge r)$

p	q	r	$\neg q$	$\neg q \wedge r$	$p \rightarrow (\neg q \wedge r)$
T	T	T	F	F	F
T	T	F	F	F	F
T	F	T	T	T	T
T	F	F	T	F	F
F	T	T	F	F	T
F	T	F	F	F	T
F	F	T	T	T	T
F	F	F	T	F	T

Precedence of Logical Operators

- Just as in algebra, operators have precedence

$$4+3*2 = 4+(3*2), \qquad \text{not } (4+3)*2$$

- Example

This means that

$p \lor q \land \neg r \rightarrow s \leftrightarrow t$

yields: $(p \lor (q \land (\neg r)) \rightarrow s) \leftrightarrow (t)$

Operator	Precedence
$\neg$	1
$\land$	2
$\lor$	3
$\rightarrow$	4
$\leftrightarrow$	5

Truth Tables

- Construct the truth table of following compound propositions
  - $p \rightarrow \neg p$
  - $p \oplus p$
  - $(q \rightarrow \neg p) \leftrightarrow (p \leftrightarrow q)$

Chapter Reading

- ***Chapter 1***, ***Topic # 1.1***, Kenneth H. Rosen, Discrete Mathematics and Its Applications

Chapter Exercise (For Practice)

- Question # 1, 2, 3, 4, 8, 9, 13, 24, 27, 28, 31, 32