Module 5
Software Testing

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SCSE

Syllabus

Module 5

Logic Based Testing: Overview, decision tables, path expressions, kv charts, specifications.

LOGIC BASED TESTING:

- Understand the concept of Logic based testing.
- Learn about Decision Tables and their application
- Understand the use of decision tables in test-case design and know their limitations.
- Understand and interpret KV Charts and know their limitations.
- Learn how to transform specifications into sentences and map them into KV charts.
- Understand the importance of dont-care conditions.

OVERVIEW OF LOGIC BASED TESTING

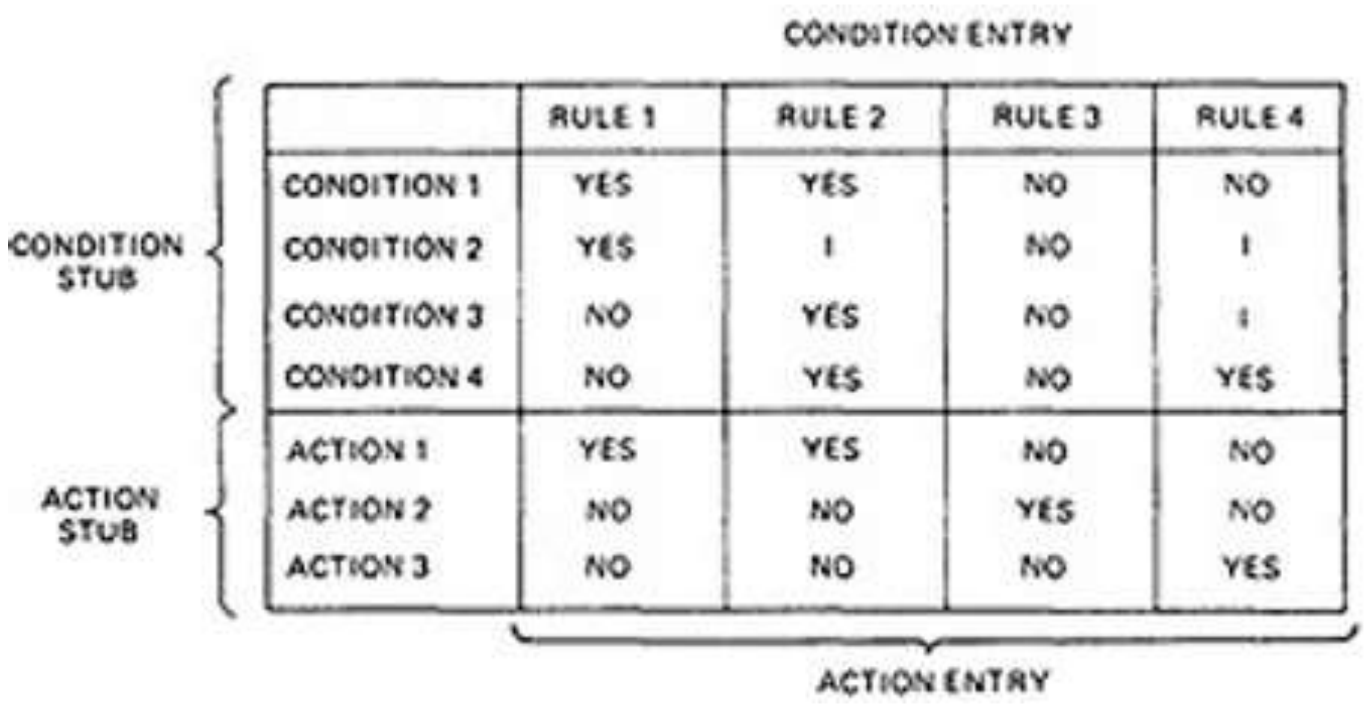
- The functional requirements of many programs can be specified by **decision tables**, which provide a useful basis for program and test design.
- Consistency and completeness can be analysed by using Boolean algebra, which can also be used as a basis for test design. Boolean algebra is trivialized by using **Karnaugh-Veitch charts**.
- "Logic" is one of the most often used words in programmers' vocabularies but one of their least used techniques.
- Logic has been, for several decades, the primary tool of hardware logic designers.
- Many test methods developed for hardware logic can be adapted to software logic testing. Because hardware testing automation is 10 to 15 years ahead of software testing automation, hardware testing methods and its associated theory is a fertile ground for software testing methods.
- As programming and test techniques have improved, the bugs have shifted closer to the process front end, to requirements and their specifications. These bugs range from 8% to 30% of the total and because they're first-in and last-out, they're the costliest of all.
- The trouble with specifications is that they're hard to express.
- Boolean algebra (also known as the sentential calculus) is the most basic of all logic systems.
- Higher-order logic systems are needed and used for formal specifications.
- Much of logical analysis can be and is embedded in tools. But these tools incorporate methods to simplify, transform, and check specifications, and the methods are to a large extent based on boolean algebra.
- Decision tables are extensively used in business data processing; Decision-table preprocessors as extensions to COBOL are in common use; boolean algebra is embedded in the implementation of these processors.
- Although programmed tools are nice to have, most of the benefits of boolean algebra can be reaped by wholly manual means if you have the right conceptual tool: the Karnaugh-Veitch diagram is that conceptual tool.

KNOWLEDGE BASED SYSTEM:

- The **knowledge-based system** (also expert system, or "artificial intelligence" system) has become the programming construct of choice for many applications that were once considered very difficult.
- Knowledge-based systems incorporate knowledge from a knowledge domain such as medicine, law, or civil engineering into a database. The data can then be queried and interacted with to provide solutions to problems in that domain.
- One implementation of knowledge-based systems is to incorporate the expert's knowledge into a set of rules. The user can then provide data and ask questions based on that data.
- The user's data is processed through the rule base to yield conclusions (tentative or definite) and requests for more data. The processing is done by a program called the **inference engine**.
- Understanding knowledge-based systems and their validation problems requires an understanding of formal logic.

DECISION TABLES

- Figure below has a limited - entry decision table. It consists of four areas called the condition stub, the condition entry, the action stub, and the action entry.
- Each column of the table is a rule that specifies the conditions under which the actions named in the action stub will take place.
- The condition stub is a list of names of conditions.



CONDITION ENTRY

		RULE 1	RULE 2	RULE 3	RULE 4
CONDITION STUB	CONDITION 1	YES	YES	NO	NO
	CONDITION 2	YES	I	NO	I
	CONDITION 3	NO	YES	NO	I
	CONDITION 4	NO	YES	NO	YES
ACTION STUB	ACTION 1	YES	YES	NO	NO
	ACTION 2	NO	NO	YES	NO
	ACTION 3	NO	NO	NO	YES

ACTION ENTRY

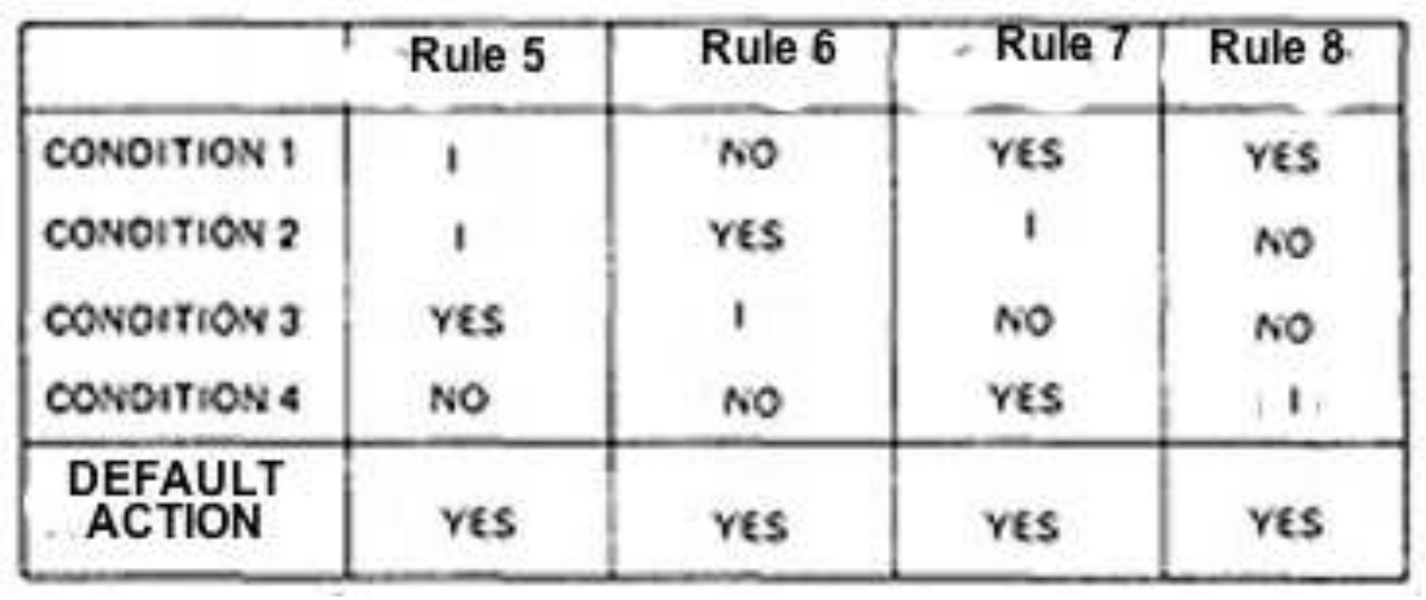
Printer troubleshooter

		Rules							
Conditions	Printer does not print	Y	Y	Y	Y	N	N	N	N
	A red light is flashing	Y	Y	N	N	Y	Y	N	N
	Printer is unrecognised	Y	N	Y	N	Y	N	Y	N
Actions	Check the power cable			X					
	Check the printer-computer cable	X		X					
	Ensure printer software is installed	X		X		X		X	
	Check/replace ink	X	X			X	X		
	Check for paper jam		X		X				

- A rule specifies whether a condition should or should not be met for the rule to be satisfied. "YES" means that the condition must be met, "NO" means that the condition must not be met, and "I" means that the condition plays no part in the rule, or it is immaterial to that rule.
- The action stub names the actions the routine will take or initiate if the rule is satisfied. If the action entry is "YES", the action will take place; if "NO", the action will not take place.
- The table in Figure can be translated as follows:

  Action 1 will take place if conditions 1 and 2 are met and if conditions 3 and 4 are not met (rule 1) or if conditions 1, 3, and 4 are met (rule 2).
- "Condition" is another word for predicate.
- Decision-table uses "condition" and "satisfied" or "met". Let us use "predicate" and TRUE / FALSE.
- Now the above translations become:
  - Action 1 will be taken if predicates 1 and 2 are true and if predicates 3 and 4 are false (rule 1), or if predicates 1, 3, and 4 are true (rule 2).
  - Action 2 will be taken if the predicates are all false, (rule 3).
  - Action 3 will take place if predicate 1 is false and predicate 4 is true (rule 4).

- In addition to the stated rules, we also need a **Default Rule** that specifies the default action to be taken when all other rules fail. The default rules for



	Rule 5	Rule 6	Rule 7	Rule 8
CONDITION 1	I	NO	YES	YES
CONDITION 2	I	YES	I	NO
CONDITION 3	YES	I	NO	NO
CONDITION 4	NO	NO	YES	I
DEFAULT ACTION	YES	YES	YES	YES

DECISION-TABLE PROCESSORS

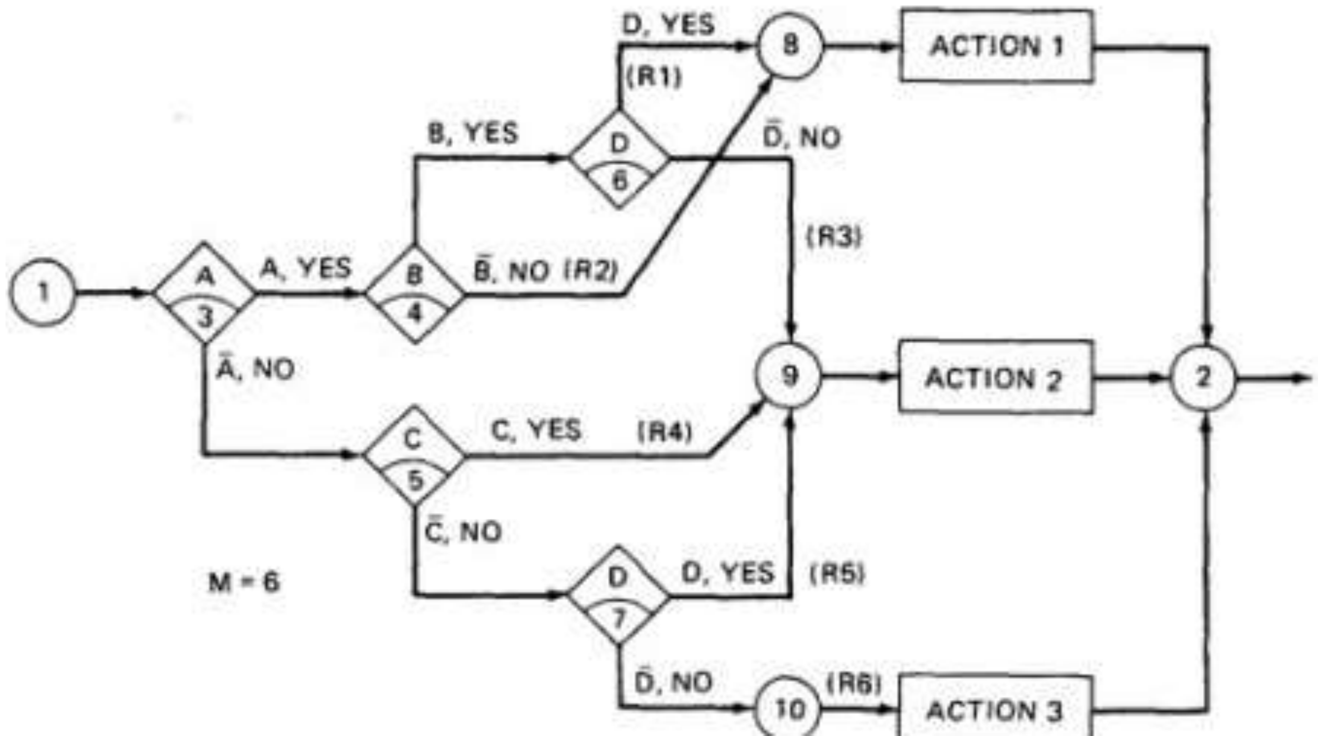
- Decision tables can be automatically translated into code and, as such, are a higher-order language
- If the rule is satisfied, the corresponding action takes place
- Otherwise, rule 2 is tried. This process continues until either a satisfied rule results in an action or no rule is satisfied and the default action is taken.
- Decision tables have become a useful tool in the programmers kit, in business data processing.

DECISION-TABLES AS BASIS FOR TEST CASE DESIGN

- The specification is given as a decision table or can be easily converted into one.
- The order in which the predicates are evaluated does not affect interpretation of the rules or the resulting action - i.e., an arbitrary permutation of the predicate order will not, or should not, affect which action takes place.
- The order in which the rules are evaluated does not affect the resulting action - i.e., an arbitrary permutation of rules will not, or should not, affect which action takes place.
- Once a rule is satisfied and an action selected, no other rule need be examined.
- If several actions can result from satisfying a rule, the order in which the actions are executed doesn't matter

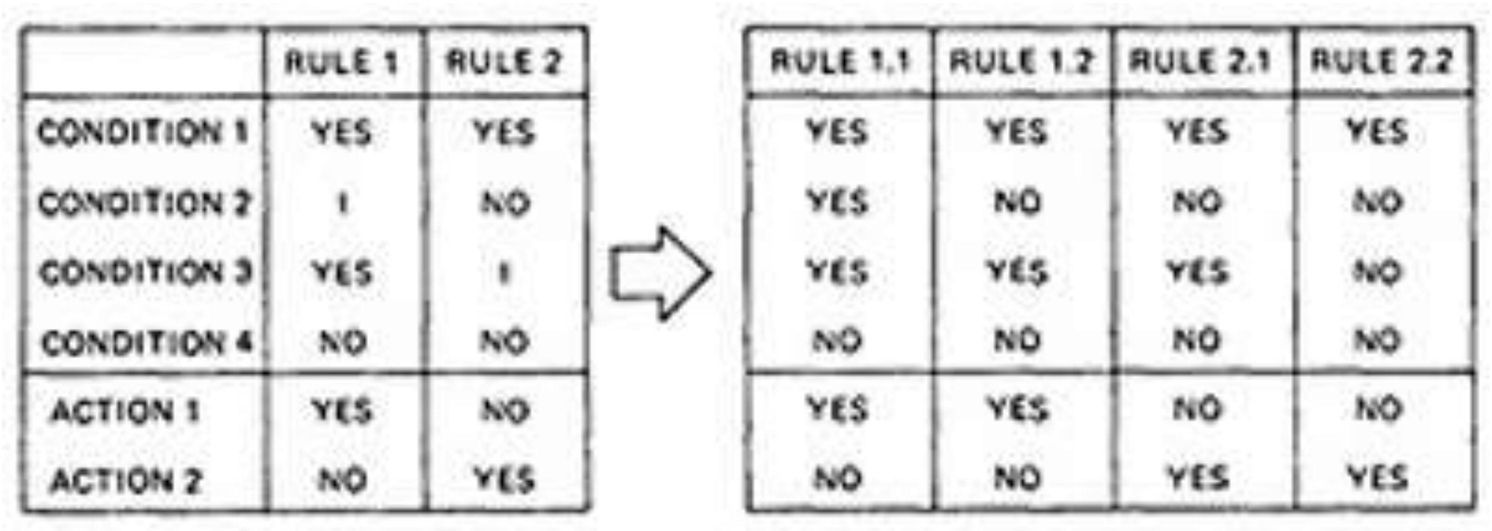
DECISION-TABLES AND STRUCTURE

- Decision tables can also be used to examine a program's structure.
- Below figure shows a program segment that consists of a decision tree.
- These decisions, in various combinations, can lead to actions 1, 2, or 3.
- If the decision appears on a path, put in a YES or NO as appropriate. If the decision does not appear on the path, put in an I, Rule 1 does not contain decision C, therefore its entries are: YES, YES, I, YES.



	RULE 1	RULE 2	RULE 3	RULE 4	RULE 5	RULE 6
CONDITION A	YES	YES	YES	NO	NO	NO
CONDITION B	YES	NO	YES	I	I	I
CONDITION C	I	I	I	YES	NO	NO
CONDITION D	YES	I	NO	I	YES	NO
ACTION 1	YES	YES	NO	NO	NO	NO
ACTION 2	NO	NO	YES	YES	YES	NO
ACTION 3	NO	NO	NO	NO	NO	YES

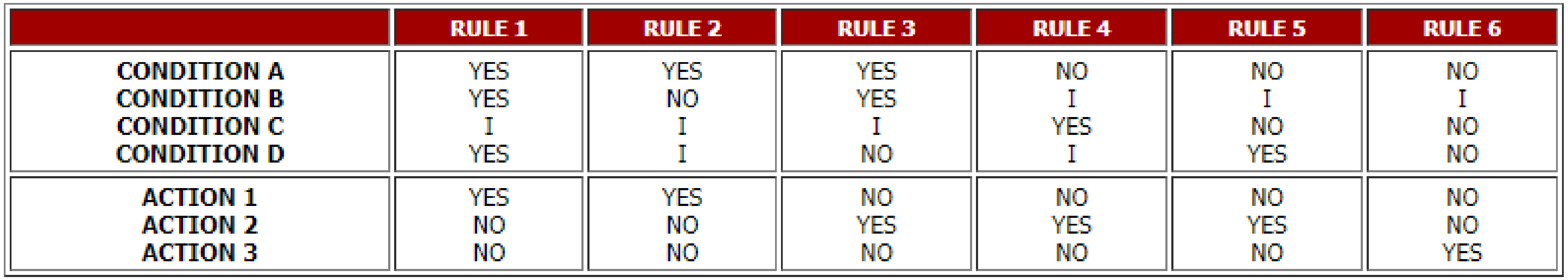
- As an example, expanding the immaterial cases results as below



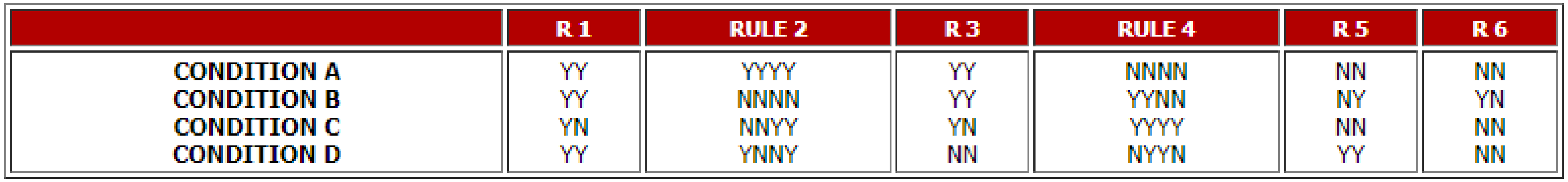
	RULE 1	RULE 2
CONDITION 1	YES	YES
CONDITION 2	I	NO
CONDITION 3	YES	I
CONDITION 4	NO	NO
ACTION 1	YES	NO
ACTION 2	NO	YES

RULE 1.1	RULE 1.2	RULE 2.1	RULE 2.2
YES	YES	YES	YES
YES	NO	NO	NO
YES	YES	YES	NO
NO	NO	NO	NO
YES	YES	NO	NO
NO	NO	YES	YES

- Similarly, If we expand the immaterial cases for the previous Table.



	RULE 1	RULE 2	RULE 3	RULE 4	RULE 5	RULE 6
CONDITION A CONDITION B CONDITION C CONDITION D	YES YES I YES	YES NO I I	YES YES I NO	NO I YES I	NO I NO YES	NO I NO NO
ACTION 1 ACTION 2 ACTION 3	YES NO NO	YES NO NO	NO YES NO	NO YES NO	NO YES NO	NO NO YES



	R 1	RULE 2	R 3	RULE 4	R 5	R 6
CONDITION A CONDITION B CONDITION C CONDITION D	YY YY YN YY	YYYY NNNN NNYY YNNY	YY YY YN NN	NNNN YYNN YYYY NYYN	NN NY NN YY	NN YN NN NN

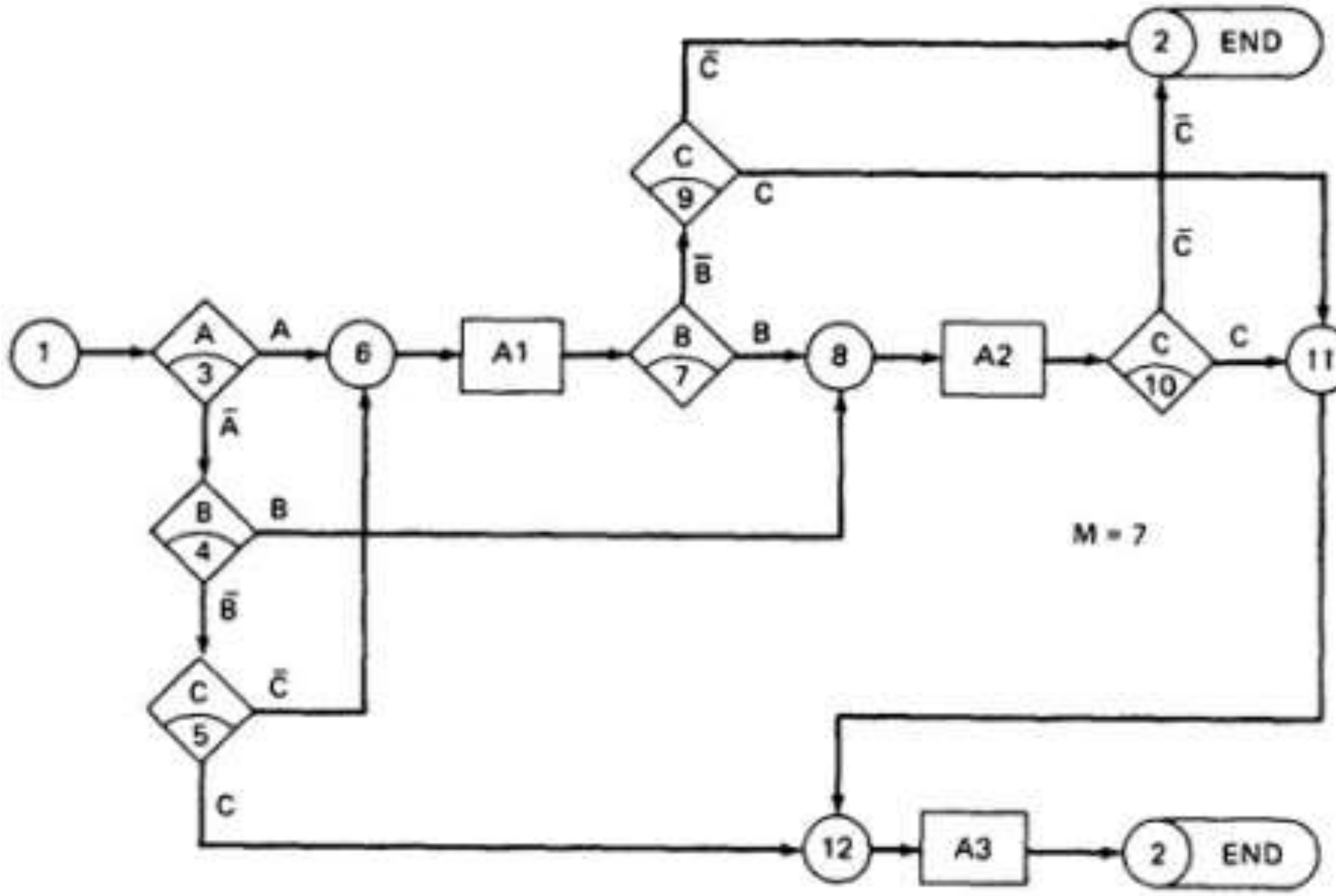
- Sixteen cases are represented in Table 1, and no case appears twice.
- Consequently, the flow graph appears to be complete and consistent.
- As a first check, before you look for all sixteen combinations, count the number of Y's and N's in each row. They should be equal. We can find the bug that way.

PATH EXPRESSIONS

- Logic-based testing is structural testing when it's applied to structure (e.g., control flow graph of an implementation); it's functional testing when it's applied to a specification.
- In logic-based testing we focus on the truth values of control flow predicates.
- A **predicate** is implemented as a process whose outcome is a truth-functional value.
- For our purpose, logic-based testing is restricted to binary predicates.
- We start by generating path expressions by path tracing as in last unit, but this time, our purpose is to convert the path expressions into boolean algebra, using the predicates' truth values (e.g., A and) as weights.

BOOLEAN ALGEBRA

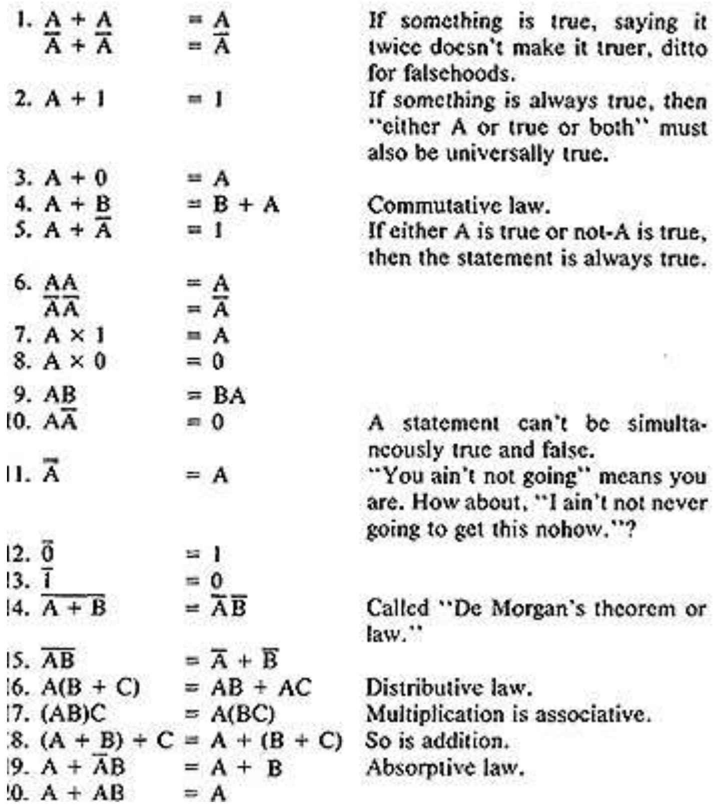
- Label each decision with an uppercase letter that represents the truth value of the predicate. The YES or TRUE branch is labelled with a letter (say A) and the NO or FALSE branch with the same letter overscored (say compliment of A).
- The truth value of a path is the product of the individual labels. Concatenation or products mean "AND". For example, the straight-through path of Figure 5.5, which goes via nodes 3, 6, 7, 8, 10, 11, 12, and 2, has a truth value of ABC. The path via nodes 3, 6, 7, 9 and 2 has a value of ABC’.
- If two or more paths merge at a node, the fact is expressed by use of a plus sign (+) which means "OR".



$$N6 = A + \bar{A}\bar{B}\bar{C}$$
$$N8 = (N6)B + \bar{A}B = AB + \bar{A}\bar{B}\bar{C}B + \bar{A}B$$
$$N11 = (N8)C + (N6)\bar{B}C$$
$$N12 = N11 + \bar{A}\bar{B}C$$
$$N2 = N12 + (N8)\bar{C} + (N6)\bar{B}\bar{C}$$

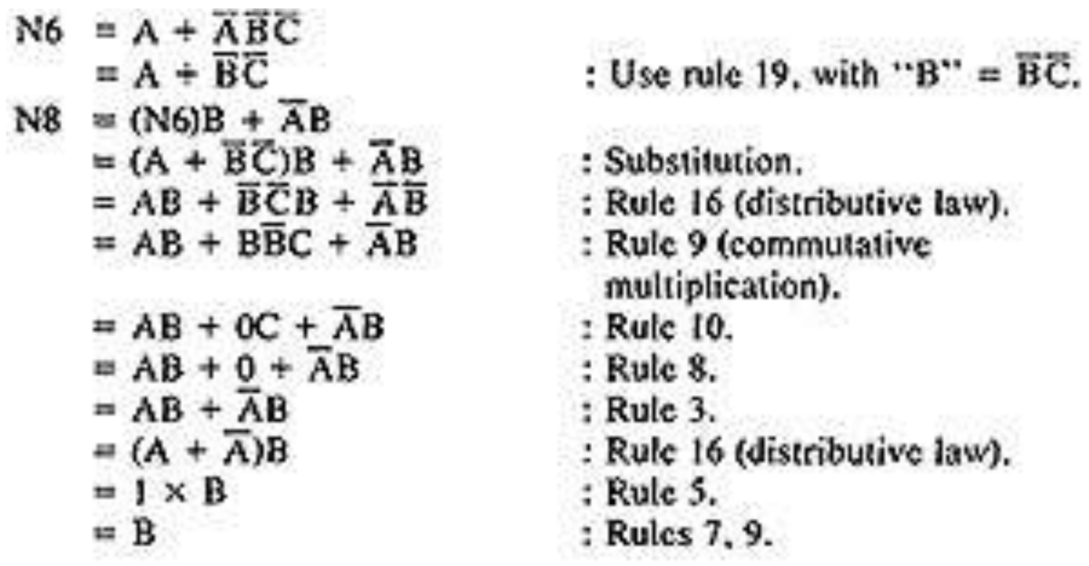
RULES OF BOOLEAN ALGEBRA

- Boolean algebra has three operators: X (AND), + (OR) and (NOT)
- **X :** meaning AND. Also called multiplication. A statement such as AB (A X B) means "A and B are both true". This symbol is usually left out as in ordinary algebra.
- **+ :** meaning OR. "A + B" means "either A is true or B is true or both".
- meaning NOT. Also negation or complementation. This is read as either "not A" or "A bar". The entire expression under the bar is negated.



1. $A + A$	$= A$	If something is true, saying it twice doesn't make it truer, ditto for falsehoods.
$\overline{A} + \overline{A}$	$= \overline{A}$	
2. $A + 1$	$= 1$	If something is always true, then "either A or true or both" must also be universally true.
3. $A + 0$	$= A$	
4. $A + B$	$= B + A$	Commutative law.
5. $A + \overline{A}$	$= 1$	If either A is true or not-A is true, then the statement is always true.
6. AA	$= A$	
$\overline{A}\overline{A}$	$= \overline{A}$	
7. $A \times 1$	$= A$	
8. $A \times 0$	$= 0$	
9. AB	$= BA$	
10. $A\overline{A}$	$= 0$	A statement can't be simultaneously true and false.
11. $\overline{\overline{A}}$	$= A$	"You ain't not going" means you are. How about, "I ain't not never going to get this nohow."?
12. $\overline{0}$	$= 1$	
13. $\overline{1}$	$= 0$	
14. $\overline{A + B}$	$= \overline{A}\overline{B}$	Called "De Morgan's theorem or law."
15. $\overline{AB}$	$= \overline{A} + \overline{B}$	
16. $A(B + C)$	$= AB + AC$	Distributive law.
17. $(AB)C$	$= A(BC)$	Multiplication is associative.
18. $(A + B) + C$	$= A + (B + C)$	So is addition.
19. $A + \overline{A}B$	$= A + B$	Absorptive law.
20. $A + AB$	$= A$	

- In all of the above, a letter can represent a single sentence or an entire boolean algebra expression.
- Individual letters in a boolean algebra expression are called **Literals** (e.g. A,B)
- The product of several literals is called a **product term** (e.g., ABC, DE).
- An arbitrary boolean expression that has been multiplied out so that it consists of the sum of products (e.g., ABC + DEF + GH) is said to be in **sum-of-products form**.
- The result of simplifications (using the rules above) is again in the sum of product form and each product term in such a simplified version is called a **prime implicate**. For example, ABC + AB + DEF reduces by rule 20 to AB + DEF; that is, AB and DEF are prime implicates.
- The path expressions of Figure can now be simplified by applying the rules.



$$\begin{aligned}
N6 &= A + \overline{A}\overline{B}\overline{C} \\
&= A + \overline{B}\overline{C} && \text{: Use rule 19, with ``B'' = } \overline{B}\overline{C}. \\
N8 &= (N6)B + \overline{A}B \\
&= (A + \overline{B}\overline{C})B + \overline{A}B && \text{: Substitution.} \\
&= AB + \overline{B}\overline{C}B + \overline{A}\overline{B} && \text{: Rule 16 (distributive law).} \\
&= AB + B\overline{B}C + \overline{A}B && \text{: Rule 9 (commutative multiplication).} \\
&= AB + 0C + \overline{A}B && \text{: Rule 10.} \\
&= AB + 0 + \overline{A}B && \text{: Rule 8.} \\
&= AB + \overline{A}B && \text{: Rule 3.} \\
&= (A + \overline{A})B && \text{: Rule 16 (distributive law).} \\
&= 1 \times B && \text{: Rule 5.} \\
&= B && \text{: Rules 7, 9.}
\end{aligned}$$

$$
\begin{array}{lll}
N11 & = (N8)C + (N6)\overline{B}C & \\
 & = BC + (A + \overline{B}\,\overline{C})\overline{B}C & \text{: Substitution.} \\
 & = BC + A\overline{B}C & \text{: Rules 16, 9, 10, 8, 3.} \\
 & = C(B + \overline{B}A) & \text{: Rules 9, 16.} \\
 & = C(B + A) & \text{: Rule 19.} \\
 & = AC + BC & \text{: Rules 16, 9, 9, 4.} \\
N12 & = N11 + \overline{A}\,\overline{B}C & \\
 & = AC + BC + \overline{A}\,\overline{B}C & \\
 & = C(B + \overline{A}\,\overline{B}) + AC & \\
 & = C(\overline{A} + B) + AC & \\
 & = C\overline{A} + AC + BC & \\
 & = C + BC & \\
 & = C & \\
N2 & = N12 + (N8)\overline{C} + (N6)\overline{B}\,\overline{C} & \\
 & = C + B\overline{C} + (A + \overline{B}\,\overline{C})\overline{B}\,\overline{C} & \\
 & = C + B\overline{C} + \overline{B}\,\overline{C} & \\
 & = C + \overline{C}(B + \overline{B}) & \\
 & = C + \overline{C} & \\
 & = 1 &
\end{array}
$$