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BCA Honours | Semester I | Calicut University

Discrete Structures for Computer Applications

Course Code: BCA1CJ103 • Module 1 Notes

MODULE I: MATHEMATICAL LOGIC AND FORMAL PROOFS

1. Propositional Logic and Connectives

Mathematical logic provides the formal syntax and semantics for reasoning about computational statements, verifying program correctness, and synthesizing digital circuits. A **proposition** is a declarative sentence that is either true (T or 1) or false (F or 0), but not both.

Logical Connectives and Truth Functions

- **Negation ($ eg$sim) :< /strong > Invertstruthvalue. eg pisfalseifp$ is true.**
- **Conjunction ($land$): Logical AND. $plandq$ is true if and only if both p and q are true.**
- **Disjunction (lor): Logical inclusive OR. $plorq$ is true if at least one operand is true.**
- **Conditional (Implication $\rightarrow$): $p \rightarrow q$ ("if p, then q"). The only case where $p \rightarrow q$ is false is when hypothesis p is true and conclusion q is false. Equivalent to $ eg p lor q$.**
- **Biconditional ($leftrightarrow$): $pleftrightarrowq$ ("p if and only if q"). True when both operands share identical truth values. Equivalent to $(p \rightarrow q)land(q \rightarrow p)$.**

2. Tautologies, Equivalences, and Rules of Inference

A compound proposition is a tautology if it evaluates to true under every possible truth assignment to its variables. It is a contradiction if it is always false, and a contingency if it can be either true or false.

- **De Morgan's Laws: $ eg(p land q) equiv eg p lor eg q$and eg(p lor q) equiv eg p land eg q$.**
- **Distributive Laws: $pland(qlorr)equiv(plandq)lor(plandr)$ and $plor(qlandr)equiv(plorq)land(plorr)$.**
- **Contrapositive Identity: $p \rightarrow q equiv eg q \rightarrow eg p$.**
- **Rules of Inference:**
  - ***Modus Ponens:* From p and $p \rightarrow q$, conclude q.**
  - ***Modus Tollens:* From $ eg qandp \rightarrow q$, conclude eg p$.**
  - ***Hypothetical Syllogism:* From $p \rightarrow q$ and $q \rightarrow r$, conclude $p \rightarrow r$.**

3. Illustrative Computational Working: Step-by-Step Numerical Example

Worked Example: Truth Table Verification and Formal Validity Proof

Problem Statement:

1. Construct a complete truth table for the compound proposition:

$$[(p \rightarrow q)land(q \rightarrow r)] \rightarrow (p \rightarrow r)$$

Prove whether this proposition is a tautology (Hypothetical Syllogism).

2. Express the argument in propositional logic and verify its formal validity:

"If the processor overheats, the cooling fan spins at maximum speed.
The cooling fan is not spinning at maximum speed.
Therefore, the processor has not overheated."

Solution & Step-by-Step Working:

Part 1: Truth Table Construction

With 3 propositional variables (p, q, r), there are $2^3 = 8$ truth assignments:

p	q	r	$p \to q$	$q \to r$	$A : (p \to q) land (q \to r)$	$p \to r$	$A \to (p \to r)$
T	T	T	T	T	T	T	T
T	T	F	T	F	F	F	T
T	F	T	F	T	F	T	T
T	F	F	F	T	F	F	T
F	T	T	T	T	T	T	T
F	T	F	T	F	F	T	T
F	F	T	T	T	T	T	T
F	F	F	T	T	T	T	T

Conclusion 1: Since the final column contains strictly True (T) for all possible truth evaluations, the proposition is proven to be a Tautology.

Part 2: Formal Validity Proof of the Verbal Argument

Assign atomic propositions:

- **Let P: "The processor overheats."**
- **Let Q: "The cooling fan spins at maximum speed."**

Formalizing the premises and conclusion:

- **Premise 1: $P \to Q$**
- **Premise 2: $ eg Q$**
- **Conclusion: $ herefore eg P$**

Deductive Proof via Modus Tollens:

1. **$P \to Q$ (Premise 1)**
2. **$ eg Q$ (Premise 2)**
3. **$ eg P$ (From 1 and 2 by Modus Tollens)**

Conclusion 2: The argument is formally valid and sound.

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Advanced Theoretical Extensions & Industrial Systems Synthesis

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1. Contemporary Engineering Dilemmas and Architectural Solutions

Organizations and software architects managing Discrete Structures for Computer Applications must systematically navigate complex computational trade-offs:

- **Computational Precision versus Execution Latency: In numerical computing and algorithmic workflows related to Propositional Logic and Inference, arbitrary-precision arithmetic eliminates floating-point rounding errors and catastrophic cancellation, but introduces substantial runtime overhead compared to hardware-accelerated IEEE 754 single- and double-precision floating-point arithmetic. High-performance computational frameworks dynamically adjust numerical precision based on problem conditioning and error-tolerance thresholds.**
- **Theoretical Purity versus Practical Memory Constraints: While mathematical abstractions often assume infinite address spaces and unbounded memory arrays, real-world implementations must operate within strict L1/L2/L3 cache hierarchies, virtual memory page tables, and hardware memory bandwidth ceilings. Structuring algorithms for spatial and temporal cache locality dramatically accelerates execution throughput.**
- **Deterministic Standardization versus Dynamic Agility: Enterprise systems require standardized standard operating procedures (SOPs) and formal verification to maintain reproducibility and auditability, while modern agile development mandates rapid iteration and adaptive architectural refactoring.**

2. Empirical Comparative Framework

A structured comparative assessment clarifies operational distinctions across conventional and contemporary paradigms in Discrete Structures for Computer Applications:

Evaluation Dimension	Conventional Traditional Practice	Contemporary Integrated Paradigm	Strategic Impact Metric
Analytical Methodology	**Manual heuristic calculation relying on static, disconnected analytical models.**	**Automated high-throughput computation utilizing optimized vector libraries (BLAS, LAPACK, NumPy) and parallel GPU acceleration.**	**Orders-of-magnitude reduction in computation latency and elimination of human clerical error.**
System Integration	**Isolated functional silos characterized by localized data stores and fragmented reporting.**	**Interoperable service-oriented architectures communicating via standardized REST, gRPC, and message-driven data streams.**	**Seamless end-to-end data pipelines and real-time operational observability.**

Evaluation Dimension	Conventional Traditional Practice	Contemporary Integrated Paradigm	Strategic Impact Metric
Risk & Governance Architecture	Periodic manual code inspections and statutory compliance reviews.	Automated static code analysis, formal software verification, continuous integration testing, and cryptographic audit trails.	Comprehensive intellectual property protection and provable statutory compliance.
Scalability & Resource Allocation	Static on-premise hardware provisioning with rigid capacity limits.	Dynamic containerized virtualization (Docker, Kubernetes) responsive to real-time workload fluctuations.	Optimized infrastructure utilization, high availability, and reduced operational expenditures.

3. Step-by-Step Implementation and Operational Governance Roadmap

Executing enterprise-grade implementations of Discrete Structures for Computer Applications requires an organized four-phase engineering roadmap:

- **Phase I: Baseline Assessment & Mathematical Scoping: Benchmarking current computational capabilities, establishing formal input-output specifications, identifying edge cases, and conducting numerical error sensitivity audits.**
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Industrial Risk Governance, Statutory Compliance & Failure Mode Analysis

Computational systems must withstand rigorous scrutiny across legal, ethical, operational, and data-integrity dimensions. Software architects deploy structured risk evaluation matrices to eliminate vulnerabilities across four core exposure categories:

Risk Category	Primary Sources of Vulnerability	Diagnostic Warning Indicators	Mitigation Protocol & Internal Controls
Numerical & Algorithmic Risk	Ill-conditioned matrices, division by zero, arithmetic overflow/underflow, non-terminating loops.	Loss of significant digits, NaN/Infinity propagation, execution timeouts, diverging residuals.	Condition number monitoring, robust numerical pivoting, loop invariant assertions, automated fuzz testing.
System & Architectural	Memory leaks, thread race conditions, buffer	Steadily escalating RAM consumption,	Memory profiling (Valgrind,

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Cybersecurity Risk	Unauthorized remote code execution, SQL/code injection, unencrypted communication channels.	Spikes in failed authentication attempts, abnormal outbound socket connections, checksum mismatches.	Input sanitization, parameterized queries, TLS 1.3 cryptographic transport, least-privilege service accounts.
Statutory & Regulatory Risk	Non-compliance with national data protection laws (DPDP Act, GDPR), licensing violations, audit failures.	Unencrypted storage of sensitive user records, unlogged administrative data modifications.	Automated data-at-rest encryption (AES-256), immutable audit logging, periodic third-party security audits.

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