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BCA Honours | Semester IV | BCA4CJ206

Python Programming

Module 2 Comprehensive Notes

Module 2: Functions, Modular Architecture, and Object-Oriented Programming

Structuring computational procedures into modular functions and encapsulating state and behavior within classes are foundational software engineering paradigms in Python.

2.1 Function Design and Parameter Passing Conventions

Functions are defined using the `def` keyword. In Python, all arguments are passed by **object reference** (call by sharing). If an argument references a mutable object (e.g., a list or dictionary), in-place modifications made within the function body mutate the caller's object.

Flexible Parameter Paradigms

- **Positional and Keyword Arguments:** Arguments passed by position or explicitly mapped by parameter name.
- **Default Arguments:** Evaluated once at function definition time (avoid mutable defaults like `[]` or `{}`).
- **Arbitrary Positional Arguments (`*args`):** Packs variable positional inputs into an immutable tuple.
- **Arbitrary Keyword Arguments (`**kwargs`):** Packs extraneous key-value arguments into a dictionary.
- **Lambda Functions:** Anonymous inline functions expressed via `lambda arguments: expression`, frequently deployed with `map()` and `filter()`.

2.2 Variable Scope and the LEGB Rule

Name resolution in Python follows the strict **LEGB Hierarchy**: Local → Enclosing (in nested functions) → Global → Built-in. To modify a global variable inside a local scope, the `global` keyword is required; to modify an enclosing variable in nested closures, the `nonlocal` keyword is used.

2.3 Object-Oriented Programming (OOP) in Python

Python is a multi-paradigm language where everything is an object instantiated from a class.

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1. Classes, Objects, and the `__init__` Constructor

```
class BankAccount:
    interest_rate = 0.04  # Class variable shared across all instances

    def __init__(self, account_holder: str, initial_balance: float):
        self.account_holder = account_holder      # Public instance variable
        self._account_number = id(self)           # Protected convention
        self.__balance = initial_balance          # Private (mangled to _BankAccount__balance)

    def deposit(self, amount: float) -> None:
        if amount > 0:
            self.__balance += amount

    def get_balance(self) -> float:
        return self.__balance
```

2. The Four Core OOP Pillars

1. **Encapsulation:** Bundling data and methods operating on that data within a unified class, hiding internal representation via name mangling (double underscore prefix `__`).
2. **Inheritance:** Deriving specialized child classes from parent base classes. Supports single, multiple, and multilevel inheritance. Method Resolution Order (MRO) is governed by the C3 Linearization algorithm, accessed via `super()`.
3. **Polymorphism and Duck Typing:** *"If it walks like a duck and quacks like a duck, it's a duck."* Python does not require rigid interface implementations; functions accept any object implementing the required methods. Operator overloading is implemented via dunder methods (e.g., `__add__`, `__str__`, `__len__`).
4. **Abstraction:** Defining abstract interface contracts using the standard `abc` (Abstract Base Classes) module and the `@abstractmethod` decorator, forcing derived subclasses to provide concrete implementations.

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1. Architectural Trade-offs and Computational Complexity

Software architects and systems engineers designing scalable computational pipelines centered on Python Programming must methodically navigate core trade-offs:

- **Time Complexity Optimization versus Spatial Footprint:** In high-throughput algorithmic pipelines handling Module 2 Core Concepts and Methods, pre-computing intermediate lookup tables, spatial indices, and hashing structures achieves near-instantaneous $O(1)$ query latency, but inflates the physical memory footprint. Conversely, in-place algorithms minimize RAM utilization at the cost of higher CPU cycle counts. Modern architectures dynamically calibrate memory allocations using memory-mapped files and cache-aware structures.

- **Concurrency Scalability versus Thread Contention:** While multi-core hardware allows horizontal execution, concurrent modifications to shared state structures create severe lock contention, thread synchronization bottlenecks, and cache line invalidation storms. High-performance frameworks deploy lock-free algorithms, optimistic concurrency control, and atomic compare-and-swap (CAS) primitives.
- **Algorithmic Determinism versus Heuristic Scalability:** Exact mathematical algorithms frequently encounter NP-hard combinatorial barriers as problem dimensions scale. Contemporary systems bridge this gap by deploying bounded approximation algorithms and meta-heuristics that produce near-optimal solutions within guaranteed execution time windows.

2. Empirical Comparative Framework

A structured comparative assessment clarifies operational distinctions across conventional paradigms and modern production implementations in Python Programming:

Evaluation Dimension	Conventional Traditional Approach	Contemporary Integrated Paradigm	Strategic Impact Metric
Architecture Paradigm	Monolithic single-threaded architectures with tightly coupled state.	Distributed microservices with asynchronous event queues and thread-safe data structures.	Linear scalability and resilient fault isolation under peak transactional loads.
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Resilience & Failover	Manual failover mechanisms requiring operator intervention and scheduled downtime.	Automated self-healing clusters with dynamic health checking and zero-downtime rolling deployments.	Continuous availability meeting strict 99.999% Service Level Agreements (SLAs).
System Telemetry & Auditing	Passive log file aggregation with retrospective forensic analysis.	Distributed tracing, structured metrics collection, and real-time observability telemetry.	Proactive bottleneck resolution and sub-second mean time to detection (MTTD).

3. Production Implementation Patterns and Resilience Engineering

Deploying mission-critical systems related to Python Programming requires adhering to robust production design patterns:

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- **State Immutability and Event Sourcing:** Maintaining an append-only log of immutable state changes guarantees verifiable auditability, eliminates data race hazards, and facilitates seamless system recovery.
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