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A Practical Implementation of Parking Lot Management Using Token System Based on Object-Oriented Programming (Java)

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Abstract: *With the increase in the number of people living in cities and the number of private cars, parking is becoming an issue of concern. Most parking spaces have manual parking systems, which often lead to issues such as incorrect billing, improper parking slot usage, data loss, and lack of effective tracking. Such parking systems cannot handle large volumes of cars effectively. This project aims to create and implement a parking lot management system using the token system with object-oriented programming (OOP) using Java as the programming language. The project aims to create classes representing real-world objects, such as cars, parking slots, tokens, and bills. The project will use essential OOP principles, including encapsulation, constructors, method overloading, static variables, object references, and class interactions. The study illustrates the use of OOP to create effective and efficient programming languages. OOP is more effective in creating programming languages compared to procedural programming, especially if the system is likely to increase in size. The object-oriented programming approach is more organized and flexible.*

Keywords: Object-Oriented Programming, Parking Lot Management, Token System, Java, Encapsulation, Modularity, Static Variables, Constructor Overloading

I. INTRODUCTION

A. Background of the Study

Modern cities rely on structured vehicle management systems. Parking infrastructure needs to manage large numbers of vehicles, track slot usage, generate billing information, and record transactions. Manual systems using tokens or logging systems are often inefficient. A software-based solution for managing parking infrastructure provides the necessary efficiency. However, a programming paradigm that allows for the clear and efficient modeling of real- world entities is necessary. Object-oriented programming meets this requirement.

Java, as a class-based object-oriented language, allows for the structured modeling of real-world systems using encapsulation, abstraction, inheritance, and polymorphism [1], [2].

B. Statement of the Problem

Traditional parking systems face several structural and operational problems: manual slot allocation errors, inconsistent billing systems, lack of modularity in system design, poor data encapsulation, and poor extensibility. A robust and extensible software architecture is necessary to address the following: modeling of real-world parking entities, data security and safety, easier modification and extension of the system, and automated token generation. The present research aims to address these issues with the development of a token-based parking lot management system using Object-Oriented Programming [3], [4].

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II. LITERATURE REVIEW

The evolution of programming paradigms has been widely discussed in the computer science literature. Past research in procedural programming has focused on the importance of sequential programming and function decomposition; however, these models have been found to be limited in terms of scalability and maintainability. Object-Oriented Programming (OOP) introduced a paradigm shift in software development by simulating real-world entities in software systems [5].

A. Historical Foundations

The term "Object-Oriented Programming" was coined and popularized by works of authors such as Tim Rentsch in his early writings and Bjarne Stroustrup in his works on the development of the C++ programming language [6]. These works pointed out the shortcomings of procedural programming in managing complex enterprise applications, especially with respect to code duplication, poor modularity, and difficulties in modifying existing code.

B. Practical Principles (Stroustrup)

Stroustrup's paper "What is Object-Oriented Programming" presents definitions of OOP features such as classes, inheritance, polymorphism, and abstraction [6]. The paper proves the practical applicability of OOP principles in simplifying complex applications by virtue of modularity, code reusability, and flexibility. The paper is highly applicable to parking lot management, as it deals with interactions between parking slot, token, and vehicle, each with distinct responsibilities.

C. Formal Framework (Wegner)

Peter Wegner's "Concepts and Paradigms of Object-Oriented Programming" presents a formal framework of classifying programming languages as object-based and object-oriented [7]. The framework focuses on scalability and extensibility, which is essential for enterprise applications such as parking lot management. Wegner's differentiation between class-based and inheritance-based programming languages justifies the use of Java as the implementation language.

D. Applied Literature

Recent research works in applied computer science have shown the effectiveness of OOP in areas like banking systems, reservation systems, and traffic management systems [8], [9]. These have shown the significance of encapsulation for secure data handling, inheritance for code reuse, and polymorphism for flexible code. Parking management systems have also been identified as a suitable case for demonstrating structured class interactions.

E. Gap in Existing Research

Even though slot allocation and billing mechanisms have been explored, the mapping of these implementations with theoretical OOP concepts like constructor overloading, static variables, returning objects, and arrays of objects has not been done comprehensively. This research attempts to bridge the gap by incorporating UNIT-II syllabus concepts into the research [10].

III. METHODOLOGY

A. Research Design

The methodology used in this research is qualitative, analytical, and implementation-oriented. It is a non- experimental study that uses the existing principles of software engineering and the Object-Oriented Programming concepts to create a practical system. The objective of using this methodology is to identify the causes of inefficiency in the traditional parking management systems and systematically break down these causes into structural and operational issues [1], [3].

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B. Data and Information Sources

The sources of the data used for this research are based on academic literature and industry practices. Three categories of sources were identified:

1. Foundational Literature: Literature on the principles of procedural programming and Object-Oriented Programming,definitions of software complexity, metrics of software complexity, and quality attributes such as maintainability and reusability. Classic books like Stroustrup [6] and Wegner [7].
2. Comparative Case Studies: Academic publications on the comparison of procedural programming and Object-Oriented Programming; white papers on the analysis of code metrics to prove efficiency gains using OOP; academic publications on the comparison of the scalability of OOP systems with other programming paradigms [4], [5].
3. Industry Best Practices: Documentation and design patterns from major software ecosystems (Java, C++, Python);case studies of parking management and similar infrastructure systems implemented using OOP; best practices in modular design, token-based identification, and billing automation [8], [9].

C. Analytical Framework

The analytical framework of this study is structured into four stages:

1. Identify and isolate specific limitations of the procedural paradigm.
2. Systematically map each core OOP Principle to the problem it was designed to solve (Encapsulation, Abstraction,Inheritance, Polymorphism).
3. Use deductive reasoning and existing literature to compare modularity, management of change, and isolation of faultsin OOP-based versus procedural architectures [2].
4. Provide reference code to demonstrate increased clarity, reuse, and extensibility resulting from OOP Principles.

D. Research Tools

The primary means of conducting this research involves analyzing object-oriented design principles and evaluating their practical application within the development of a Parking Lot Management System using a token-based mechanism. This study critically explores established OOP principles such as class structuring, encapsulation, construction, method overloading, static members, and object interactions, applied to the real-world parking management system [10], [11].

IV. RESULTS AND DISCUSSION

A. Core OOP Principles: Principle-to-Solution Mapping

Encapsulation: Global access to parking data causes instabilities and security issues. In the given code, attributes such as vehicleNumber, slotNumber, and tokenNumber are declared as private and accessed only through getter methods [3].

Abstraction: Excessive internal information regarding the slot allocation and billing mechanism causes complexity. Only the required public interface has been exposed, and internal details have been hidden [2].

Inheritance: Parking systems need to accommodate different vehicle types such as cars, bikes, and trucks, which share common attributes like vehicle number and type. Inheritance accommodates common attributes in a parent Vehicle class [6], [7].

Polymorphism: Excessive conditional statements for billing and slot allocation cause inflexibility. Dynamic method binding through polymorphism enables seamless implementation of the billing mechanism for different vehicle types [10].

B. Practical Implementation in Java

The system includes the following main classes: Vehicle (represents cars or bikes with attributes like number and type), Token (generates unique identifiers using static variables), ParkingSlot (models slot availability and occupancy),

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ParkingLot (manages allocation and freeing of slots), and Bill (calculates charges based on parking duration). This implementation incorporates class definitions, default and parameterized constructors, method overloading, the this keyword, static variables for token generation, objects as return types and arguments, and arrays of objects for slot grouping [9], [11].

C. Code Implementation in Java

1) Class Definition and Encapsulation:

Vehicle-related attributes are declared as private to preserve internal state integrity. Access occurs exclusively through defined getter methods, ensuring controlled interaction and encapsulation [3].

```
class Vehicle { private String
vehicleNumber; private String
vehicleType; public String
getVehicleNumber() { return
vehicleNumber; } public String
getVehicleType() { return
vehicleType; }
}
```

1) **Constructors and the this Keyword:**

The parameterized constructor initializes all essential attributes during object creation. The this keyword resolves scope ambiguity between instance variables and constructor parameters, ensuring accurate value assignment [2].

```
public Vehicle(String vehicleNumber, String
vehicleType) { this.vehicleNumber =
vehicleNumber; this.vehicleType =
vehicleType; }
```

2) **Static Variables for Token Generation:**

The Token class uses a static variable counter shared across all instances. This ensures every vehicle receives a unique token number, demonstrating class-level state management [3].

```
class Token { private static int counter =
1000; private int tokenNumber; public
Token() { tokenNumber = counter++; } public
int getTokenNumber() { return tokenNumber;
}
}
```

3) **Array of Objects:**

The ParkingLot class maintains an array of ParkingSlot objects, enabling structured representation of multiple parking slots. This demonstrates grouping of multiple objects of the same class [9].

```
class ParkingLot { private ParkingSlot[] slots;
public ParkingLot(int totalSlots) { slots = new
ParkingSlot[totalSlots]; for (int i = 0; i <
totalSlots; i++) slots[i] = new ParkingSlot(i +
1); }
}
```

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4) **Object as Return Type:**

The allocateSlot() method returns a ParkingSlot object, demonstrating the factory design pattern where a method returns an object reference [8].

```
public ParkingSlot allocateSlot() { for (ParkingSlot slot : slots) if

(slot.isAvailable()) return slot; return null;
}
public ParkingSlot getSlot(int slotNumber) { if (slotNumber
> 0 && slotNumber <= slots.length) return
slots[slotNumber - 1]; return null; }
```

5) **Object as Argument:**

The parkVehicle() method accepts a Vehicle object as an argument, demonstrating object passing between classes. Entry time is stored using System.currentTimeMillis() [9].

```
public void parkVehicle(Vehicle vehicle) { this.vehicle =
vehicle; this.entryTime = System.currentTimeMillis();
this.occupied
= true; }
```

6) **Complete Menu-Driven Main Program:**

The Main class integrates all classes through a menu-driven interface using Scanner for runtime input. It demonstrates object creation, method calls, and interaction between all defined classes [11].

```
import java.util.Scanner; public
class Main {
public static void main(String[] args) { Scanner sc =
new Scanner(System.in); ParkingLot lot = new
ParkingLot(5); while (true) { System.out.println("1.
Park Vehicle"); System.out.println("2. Exit
Vehicle"); System.out.println("3. Exit System");
System.out.print("Choose: "); int choice =
sc.nextInt(); if (choice == 1) { sc.nextLine();
System.out.print("Vehicle Number: "); String
number = sc.nextLine();
System.out.print("Vehicle Type: "); String type =
sc.nextLine();
Vehicle v = new Vehicle(number, type);
ParkingSlot slot = lot.allocateSlot(); if (slot != null)
{ slot.parkVehicle(v); Token token = new Token();
System.out.println("Parked at Slot: "
+ slot.getSlotNumber());
System.out.println("Token Number: "
+ token.getTokenNumber());
} else { System.out.println("Parking Full");
}
} else if (choice == 2) { System.out.print("Enter Slot
Number: "); int slotNum = sc.nextInt();
```

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```
ParkingSlot slot = lot.getSlot(slotNum);

    if (slot != null &&
    !slot.isAvailable()) { double bill =
    slot.removeVehicle(); System.out.println("Vehicle
    Removed."); System.out.println("Total Bill: Rs."
    + bill);
    } else { System.out.println(
    "Invalid Slot or Already Empty.");
    }
    } else { System.out.println("System Closed.");
    break; } } sc.close(); }
    }
```

B. Code Explanation

- **Classes:** A class works like a blueprint that defines what an object should contain and what it can do. In thisproject, classes like Vehicle, Token, ParkingSlot, and ParkingLot each have their own data and functions, helping organize the program properly [3].
- **Creating Objects:** To use a class, we create an object using the new keyword. When a vehicle enters, a Vehicleobject is created and its details are stored. When a ParkingSlot object is created, memory is assigned for that slot.
- **Static Variables:** All members of a class share common class variables throughout the program. In the Token class,a static counter ensures all tokens generated are unique for all vehicles, providing common state information [3].
- **Method Overloading:** Method overloading allows different methods with the same name but different parameters.In this system, billing methods can be overloaded based on parking time, vehicle type, or slot category. This is compile-time polymorphism [6].
- **Method Overriding:** Overridden methods are redefined in the child class. For example, if a Car or Bike classinherits from Vehicle, a calculateBill() method can be overridden. This is runtime polymorphism [7].
- **Constructors:** A constructor is a special method used to initialize the state of an object. Parameterized constructorsinitialize objects based on certain parameters; default constructors enable dynamic object generation [2].
- **The this Keyword:** The this keyword refers to the current instance of the class. It distinguishes instance variablesfrom parameters, ensuring proper assignment of values during object construction.
- **Object as Return Type:** Methods can return references to objects. The allocateSlot() method returns a ParkingSlotobject — an example of the factory design pattern [8].
- **Object as Argument:** An object can be passed as an argument to other methods. A Vehicle object is passed to theparkVehicle() method. This is a fundamental feature of object-oriented programming [9].
- **Array of Objects:** An array of objects groups multiple objects of the same class. The ParkingLot class maintainsan array of ParkingSlot objects, enabling structured representation of multiple parking slots [10].

E. OOP Principle Mapping Summary

The principal OOP coordination elements are summarized in Table I below.

Mechanism	Implementation Context	Functional Role
Encapsulation	private fields + getters	Protect vehicle and slot data integrity

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Abstraction	Public interface only	Hide billing and allocation logic
Inheritance	Vehicle parent class	Shared attributes for Car and Bike types
Polymorphism	Overloading / Overriding	Flexible billing mechanism
Static Variables	Token.counter	Unique token generation
Object Return	allocateSlot()	Factory-style slot assignment
Array of Objects	ParkingSlot[]	Structured slot management

TABLE I: OOP Principle-to-Implementation Mapping

V. CONCLUSION

The parking lot management system is an excellent example of the effective use of Object-Oriented Design with the help of the token-based mechanism. The classes, constructors, method overloading, object interactions, static members, and encapsulation make the parking lot management system more maintainable and scalable [3], [9].

The object-oriented approach is better than the procedural approach in the context of extensibility and modularity. This research work has covered the objectives of UNIT-II of the Object-Oriented Programming curriculum and has proven the significance of OOP in the development of management systems in the modern world [1], [2].

Database integration, GUI interface development, and the use of complex design patterns like Singleton and Factory Method for widespread deployment are some of the potential future improvements [8], [10].

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BIOGRAPHY

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