APPLICATION OF ABSTRACT DATA TYPES (ADTS) IN DEVELOPING STUDENT MANAGEMENT SYSTEM

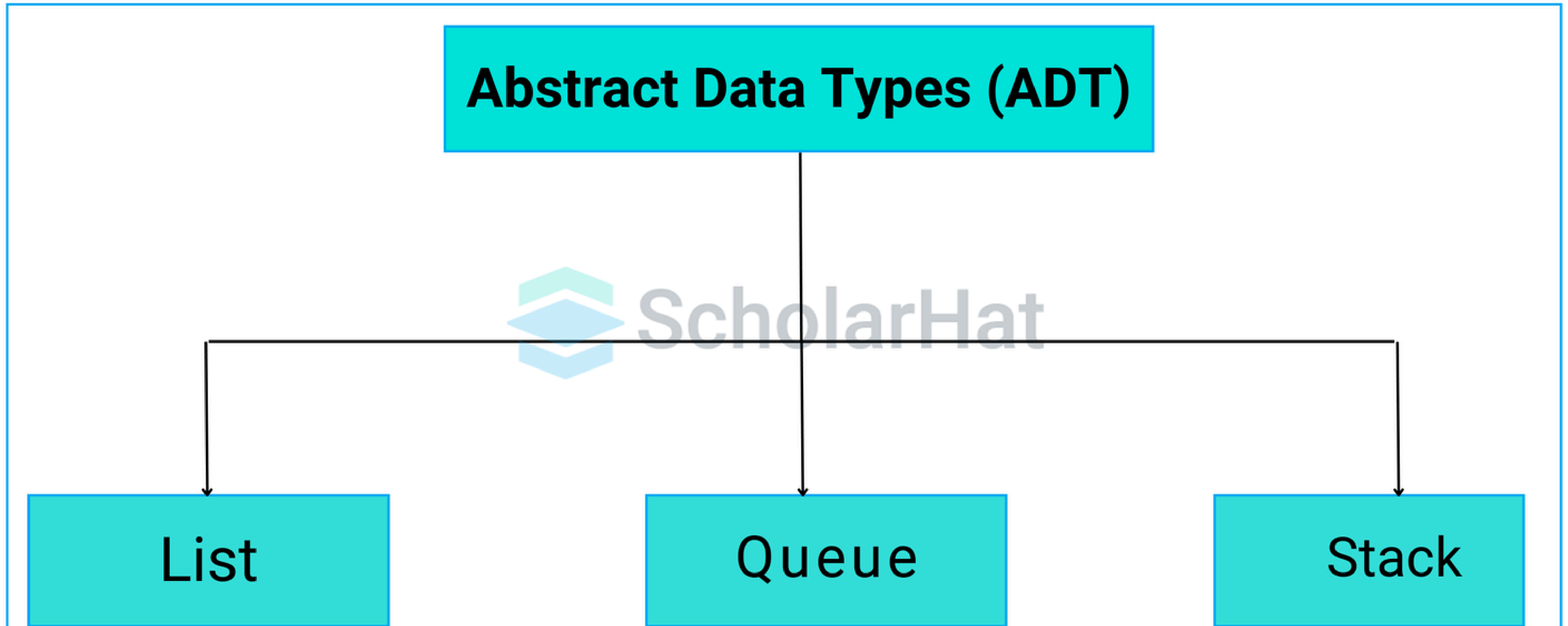
Objective & Scope

Objective:

- Explain the role of ADTs in software design.
- Illustrate through Student Management System: add, edit, delete, sort, search.
- Evaluate and compare the effectiveness of algorithms, data structures.

Scope:

- Manage student information (ID, Name, Score, Ranking).
- Functions: Add, Edit, Delete, Sort by score, Search by ID, Save & Load data.



Introduction to Abstract Data Types (ADTs)

What are ADTs?

Definition: Describes data and operations on data without worrying about implementation details.

Benefits:

- Separate interface and implementation.
- Easy to change internally without affecting the source code using ADT.
- Increased flexibility, reuse, easy to maintain.

ADTs & Applied Data Structures

- ADTs Used: Stack
- Illustrative Data Structure:

ArrayStack is used to store the list of students. It is implemented using an array, making it suitable for managing the addition and removal of students in a Last-In-First-Out (LIFO) manner. Sorting is done by converting the stack into an array, applying the sorting algorithms, and then updating the stack. This approach provides convenience for both stack operations and sorting functionality.

Real Problem & System Requirements

Context: Managing a class with a changing number of students.

Data:

Student ID (unique), Name, Score (0-10), Rating (Fail

Functions:

- Add, Edit, Delete students
- Sort by score
- Search students by ID
- Save & load data for long-term use

System Overview Architecture

System architecture diagram:

- Class `Student`: Represents student information (ID, Name, Score).
- Class `StudentStack`: Manages student stacks (push, pop, peek).
- Class `Student Management`: Coordinates student management operations (add, edit, delete, sort, search).
- Class `Main`: User interface commands.

Amount of operations:

- User input command → `Main` calls `StudentManager` → `StudentManager` interacts with `StudentStack`.

Student Class - Structure & Function

Attributes:
- `id` (String): Student code, unique.
- `name` (String): Full name of student.
- `marks` (double): Student score.

Methods:

`getId()`, `getName()`, `getMarks()`

`setName(String name)`, `setMarks(double quotes)`

`getRanking()`: Calculates the type based on the score.

Constraints:

ID is not empty.

Score from 0 to 10.

```java
private String id;
private String name;
private double marks;

public Student(String id, String name, double marks) {
    this.id = id;
    this.name = name;
    this.marks = marks;
}

public String getId() { return id; }

public String getName() { return name; }

public double getMarks() { return marks; }

public void setMarks(double marks) {
    this.marks = marks;
}

public String getRanking(){
    if (marks < 5) return "Fail";
    else if (marks < 6.5) return "Medium";
    else if (marks < 7.5) return "Good";
    else if (marks < 9.0) return "Very Good";
    else return "Excellent";
}
```

StudentsStack Class - Managing Student Rankings

Properties: - `maxSize` (int): Maximum size of the stack. - `stackArray` (Student[]): Table containing students. - `top` (int): Index of the top element in the stack. **Methods:** - `push(Student)`: Add students to the stack. - `pop()`: Removes and returns student members. - `peek()`: Views the top student without skipping. - `isEmpty()`: Checks if the classification is empty. - `isFull()`: Checks if the traf is full. - `size()`: Returns the number of students in the stack. - `clear()`: Clears all students in the stack.

```
public class StudentStack {

    int maxSize;
    private static Student[] stackArray;
    private static int top;

    public StudentStack(int size) {
        this.maxSize = size;
        this.stackArray = new Student[maxSize];
        this.top = -1; // stack is initially empty
    }

    public void push(Student student){

        if(top < maxSize - 1){
            stackArray[++top] = student;
        }
        else {
            System.out.println("Stack is full. Cannot add more students");
        }
    }
    public Student pop(){
        if (top >= 0){
            return stackArray[top--];
        }else {
            System.out.println("Stack is empty. Cannot pop.");
            return null;
        }
    }

    public Student peek(){
        if (top >= 0){
            return stackArray[top];
        }else {
            System.out.println("Stack is empty. Nothing to peek.");
            return null;
        }
    }

    public boolean isEmpty() { return (top == -1); }

    public int size() { return top + 1; }
}
```

Student Management Class - Coordinating Student Management Operations

Properties: `studentStack` (StudentStack): Student management solution.
Methods:
`addStudent(Student)`: Adds a student to the stack.
`removeStudent()`: Removes a student from the top of the stack.
`updateStudent(String id, double newMark)`: Updates a student's score by ID.
`searchStudent(String id)`: Searches for students by ID.
`sortStudents()`: Sorts students by score.
`displayStudents()`: Displays the list of students.

```java
public void displayStudent(){
    Student[] tempArr = new Student[studentStack.size()];
    int count = 0;

    while (!studentStack.isEmpty()){
        Student student = studentStack.pop();
        System.out.println(student);
        tempArr[count++] = student;
    }

    for (int i = count - 1; i >= 0; i--){
        studentStack.push(tempArr[i]);
    }
}

public boolean isEmpty() {
    return studentStack.isEmpty();
}
```

```java
public class StudentManagement {

    private StudentStack studentStack;

    public StudentManagement(int size) {
        studentStack = new StudentStack(size);
    }



    public void addStudent(Student student) {
        if (studentStack.size() >= studentStack.maxSize) {
            System.out.println("Stack is full. Cannot add more students.");
            return; // Exit without adding the student
        }
        studentStack.push(student);
    }

    public Student removeStudent() {
        if (studentStack.isEmpty()) {
            System.out.println("No student to remove. The stack is empty.");
            return null;
        }
        return studentStack.pop();
    }
```

```java
public void updateStudent(String id, double newMark) {
    // temporary store students in an array
    boolean found = false;
    Student[] tempArr = new Student[studentStack.size()];
    int count = 0;

    while (!studentStack.isEmpty()) {
        Student student = studentStack.pop();
        if (student.getId().equals(id)) {
            student.setMarks(newMark); // update mark
            found = true;
        }
        tempArr[count++] = student; // store student in tempArr
    }

    for (int i = count - 1; i >= 0; i--) {
        studentStack.push(tempArr[i]);
    }

    if (found) {
        System.out.println("Student marks updated successfully");
    } else {
        System.out.println("Student with ID " + id + " not found.");
    }
}
```

```java
public Student searchStudent(String id) {
    Student[] tempArr = new Student[studentStack.size()];
    int count = 0;

    while (!studentStack.isEmpty()) {
        Student student = studentStack.pop();
        if (student.getId().equals(id)) {
            // Found the student, push it back to the stack and return it
            for (int i = count - 1; i >= 0; i--) {
                studentStack.push(tempArr[i]);
            }
            return student; // Return the found student
        }
        tempArr[count++] = student; // Store student in tempArr
    }

    // If not found, restore all students back to the stack
    for (int i = count - 1; i >= 0; i--) {
        studentStack.push(tempArr[i]);
    }

    System.out.println("Student with ID " + id + " not found.");
    return null;
}
```

Functions: Add, Edit, Delete Students

Add Student:
- Check for incomplete classification.
- Use `push()` to add students.

Edit Student:
- Search for students by ID.
- Update scores if found.

Delete Student:
- Use `pop()` to remove students.
- Notify if not sorted empty.

Process operation:
- Call the corresponding method in `Student Management`.
- Notify the user of the result.

```java
public Student removeStudent() {
    if (studentStack.isEmpty()) {
        System.out.println("No student to remove. The stack is empty.");
        return null;
    }
    return studentStack.pop();
}
```

```java
public void addStudent(Student student) {
    if (studentStack.size() >= studentStack.maxSize) {
        System.out.println("Stack is full. Cannot add more students.");
        return; // Exit without adding the student
    }
    studentStack.push(student);
}

public Student removeStudent() {
    if (studentStack.isEmpty()) {
        System.out.println("No student to remove. The stack is empty.");
        return null;
    }
    return studentStack.pop();
}
```

```java
public void updateStudent(String id, double newMark) {
    // temporary store students in an array
    boolean found = false;
    Student[] tempArr = new Student[studentStack.size()];
    int count = 0;

    while (!studentStack.isEmpty()) {
        Student student = studentStack.pop();
        if (student.getId().equals(id)) {
            student.setMarks(newMark); // update mark
            found = true;
        }
        tempArr[count++] = student; // store student in tempArr
    }

    for (int i = count - 1; i >= 0; i--) {
        studentStack.push(tempArr[i]);
    }

    if (found) {
        System.out.println("Student marks updated successfully");
    } else {
        System.out.println("Student with ID " + id + " not found.");
    }
}
```

Big O Theory & Notation Analysis

Asymptotic Analysis (Asymptotic Analysis): Evaluate the performance of the algorithm when increasing the size of data (N).

Big O Notation: Describe the rate of increase or space of time for the input size. **Examples:** $O(1)$, $O(n)$, $O(n \log n)$, $O(n^2)$ **Meaning:** Helps choose the optimal solution when the data is large.

Complexity of Functions in the System

Add Student: Check incomplete classification: O(1) - Add to stack: O(1) **Edit Student:** - Search member: O(n) - Update number: O(1) **Delete Student:** - Remove top member: O(1) **Sort Biome:** - Use Quick Sort: O(n log n) **Search Student:** - Search by ID: O(n)

Real-world Performance Testing (Benchmark)

Purpose: Measure real-world time instead of just theoretical.
Method:
- Randomly generate 10,000 students.
- Time the execution of Bubble Sort and Quick Sort.

Expected results:
- Quick Sort is significantly faster than Bubble Sort when N is large.

```
/Library/Java/JavaVirtualMachines/jdk-21.jdk/Contents/Home/bin/
Bubble Sort Execution Time: 422015077 nanoseconds
Quick Sort Execution Time: 3024296 nanoseconds
```

```java
public void measureSortTime() {
    int numStudents = 10000;  // Ví dụ số lượng học sinh

    // Tạo sinh viên ngẫu nhiên
    Student[] students = generateRandomStudents(numStudents);

    // Đo thời gian sắp xếp Bubble Sort
    long bubbleStartTime = System.nanoTime();
    bubbleSort(students);  // Chạy Bubble Sort
    long bubbleEndTime = System.nanoTime();
    long bubbleSortDuration = bubbleEndTime - bubbleStartTime;

    // Tạo lại sinh viên ngẫu nhiên cho Quick Sort
    students = generateRandomStudents(numStudents);

    // Đo thời gian sắp xếp Quick Sort
    long quickStartTime = System.nanoTime();
    quickSort(students,  low: 0,  high: students.length - 1);  // Chạy Quick Sort
    long quickEndTime = System.nanoTime();
    long quickSortDuration = quickEndTime - quickStartTime;

    // Hiển thị kết quả
    System.out.println("Bubble Sort Execution Time: " + bubbleSortDuration + " nanoseconds");
    System.out.println("Quick Sort Execution Time: " + quickSortDuration + " nanoseconds");
}

// Tạo sinh viên ngẫu nhiên cho học sinh
private Student[] generateRandomStudents(int numStudents) {
    Random random = new Random();
    Student[] students = new Student[numStudents];
    for (int i = 0; i < numStudents; i++) {
        double marks = 0 + (10 - 0) * random.nextDouble();  // Điểm số từ 0 đến 10
        students[i] = new Student( id: "ID" + i,  name: "Student" + i, marks);
    }
    return students;
}
```

Benchmark Results - Comparing Bubble Sort & Quick Sort

Actual Results:

Bubble Sort: 422 milliseconds

Quick Sort: 30 milliseconds

Comments: Quick Sort is much faster than Bubble Sort.

Conclusion: Choosing Quick Sort to sort students is the optimal type.

```
Bubble Sort Execution Time: 422015077 nanoseconds
Quick Sort Execution Time: 3024296 nanoseconds
```

Balancing Resources & System Performance

Memory (Cache):
`StudentStack` uses continuous memory in the array.
Size limit.
CPU & Runtime:
- Optimal time processing of Quick Sort.
- Quick addition and deletion operations.

Can be used:
- Consumes memory to ensure performance.
- Suitable for current data.

Advice:
- Increase size if needed.
- Consider using other structured data if increasing capacity.

Testing & Debugging Strategy

Important testing scope:
- Ensure the system is working correctly.
- Detect and fix errors before developing the declaration.

Type checking:
- Unit testing (Unit testing): Test each individual method.
- Validity checking (Integration testing): Test the interaction between classes and components.
- System testing (System testing): Test the entire system under real-world conditions.

Debugging method:
- Use debug tool in IDE.
- Add message log to trace the execution of this flow.
- Check input data validation.

Handle user error:
- Check input data validity.
- Clear message and error correction user guide.

Using Data Structure Library (DSL): Welding & Manual Pressing

What is a data structure library (DSL)?
- A collection of classes and methods for managing data.
Advantages of DSL:
- Saves development time.
- Tested and optimized.
DSL mode:
- Limited in customization.
- Performance may not be optimal for all cases.
Reasons for manual selection:
- Full control over configuration data.
- Performance optimization for specific operations.
- Flexibility in extension and change.
Example in project:
- Use `ArrayList` for lists students.
- Using `StudentStack` to manage student stacks.

Algorithm Efficiency: Evaluation & Benchmarking

Target value: Compare the performance of sorting algorithms.

Algorithms used: Bubble sort: Simple but efficient for large data.

Quick sort: More efficient than O(n log n) complexity.

Benchmark of the method:

- Randomly generate 10,000 students with numbers from 0 to 10.
- Execute and measure the time of both algorithms.

Result:

- Quick Sort is significantly faster than Bubble Sort.

Comments:

- Choose the appropriate algorithm to improve the system efficiency.

Alternative Algorithm & Performance Evaluation

Output alternative algorithm:
Merge Sort: O(n log n) complexity, more stable than Quick Sort.
Reasons for choosing Merge Sort:
- Stable in sorting elements with equal values.
- Optimized for large and distributed data.
Cost efficiency:
- Time comparison between Quick Sort and Merge Sort on the same data.
- Merge Sort may consume more memory but provides stability.
Conclusion:
- Choosing Merge Sort is appropriate when stability and correct sorting of duplicate elements is required.

Conclusion

Summary:

- Application of ADTs improves system design and performance.
- Selection of appropriate data configuration and algorithms for improved efficiency.
- Testing and debugging to ensure software quality.

Benefits achieved:

- Effective and maintainable student management system.
- High performance in key operations.
- Scalability and operability.

THANK YOU!