**Exercise 7: Financial Forecasting**

**Understand Recursive Algorithms:**

**Recursion**

Recursion is a foundational concept in computer science wherein a function solves a problem by invoking itself with a subset or simplified version of the original input. This process continues iteratively until a well-defined termination condition—known as the **base case**—is met. At that point, the recursive calls begin to resolve in reverse order, ultimately producing the final result.

Mathematically and programmatically, recursion offers an elegant and structured approach to solving problems that exhibit **self-similar** or **divide-and-conquer** characteristics.

**How Recursion Simplifies Problem Solving**

Recursion is particularly useful for simplifying problems that are naturally hierarchical, repetitive, or decomposable. Below are key scenarios where recursion proves to be both practical and efficient:

**Recursive Decomposition**

Many problems can be decomposed into smaller subproblems of the same nature. Recursion allows a developer to write concise and intuitive code without manually managing loops, stacks, or complex state.

**Example:**  
Calculating the factorial of a number n (i.e., n!) can be expressed as:  
n! = n \* (n-1)!, with the base case 1! = 1.

**Divide-and-Conquer Algorithms**

Recursive logic is a natural fit for divide-and-conquer techniques where a problem is divided into smaller instances, solved independently, and their results combined. Algorithms like **Merge Sort**, **Quick Sort**, and **Binary Search** are classic examples where recursion significantly simplifies implementation and improves readability.

**Navigating Hierarchical Data Structures**

Recursion is instrumental in traversing hierarchical or nested structures such as:

* File systems (folders within folders)
* Trees and graphs (e.g., DOM trees, abstract syntax trees)
* JSON/XML\_parsing  
  Recursive functions can be designed to explore each level of these structures without excessive control logic.

**Benefits of Using Recursion**

* **Improved Code Clarity:** Recursive implementations are often more concise and align closely with the natural definition of the problem.
* **Scalability of Logic:** Recursive functions inherently support varying input sizes without additional control flow.
* **Alignment with Mathematical Models:** Many mathematical operations (e.g., permutations, combinations, power functions) are defined recursively and can be directly mapped into code.

**Considerations and Optimization**

While recursion offers numerous benefits, it is important to be mindful of the following considerations:

* **Stack Depth Limitation:** Excessive recursive calls can lead to a **stack overflow** error if the system's call stack is exceeded.
* **Time Complexity:** Naive recursive implementations, especially in problems involving overlapping subproblems (e.g., Fibonacci), can be inefficient unless optimized.
* **Optimizations:** Performance issues can be mitigated using techniques like:
  + **Memorization** to cache previously computed results
  + **Tail recursion** where supported, to optimize call stack usage
  + **Converting to iteration** when recursion becomes too deep or complex

**Setup – Recursive Future Value Calculation**

**Objective:**

To establish a core method that calculates the future value of an investment or metric using a **recursive algorithm** based on a given **growth rate** and **forecast period (in years)**.

**Financial Formula Overview**

The future value of an investment assuming compounded growth is typically represented by:

FutureValue=CurrentValue×(1+GrowthRate) ^n

Where:

* **CurrentValue** is the present value of the investment,
* **GrowthRate** is the annual compound growth rate (in decimal form),
* **n** is the number of periods (e.g., years) to forecast.

In recursion, instead of using exponentiation directly, we **reduce the number of years n by one in each recursive call** and apply the growth step-by-step until the base case (n == 0) is reached.

**Recursive Method Structure**

public static double calculateFutureValue(double currentValue, double growthRate, int years) {

// Base Case: If no years left to forecast, return the current value

if (years == 0) {

return currentValue;

}

// Recursive Step: Apply growth for one year, then continue with remaining years

return calculateFutureValue(currentValue \* (1 + growthRate), growthRate, years - 1);

}

**Example Usage**

public static void main(String[] args) {

double initialAmount = 10000.0;

double annualGrowth = 0.06; // 6% annual growth

int forecastPeriod = 5;

double futureValue = calculateFutureValue(initialAmount, annualGrowth, forecastPeriod);

System.out.printf("Projected Future Value after %d years: ₹%.2f%n", forecastPeriod, futureValue);

}

**Implementation:**

public class Financial

 {

    public static double calculateFutureValue(double currentValue, double annualRate, int years) {

        if (years <= 0 || currentValue <= 0) {

            return currentValue;

        }

        double updatedValue = currentValue \* (1 + annualRate);

        return calculateFutureValue(updatedValue, annualRate, years - 1);

    }

    public static void main(String[] args) {

        testForecast(10000.0, 0.05, 3);

        testForecast(15000.0, 0.08, 5);

        testForecast(0.0, 0.10, 5);

        testForecast(20000.0, 0.07, 0);

        testForecast(12000.0, 0.06, -2);

        }

    private static void testForecast(double value, double rate, int years) {

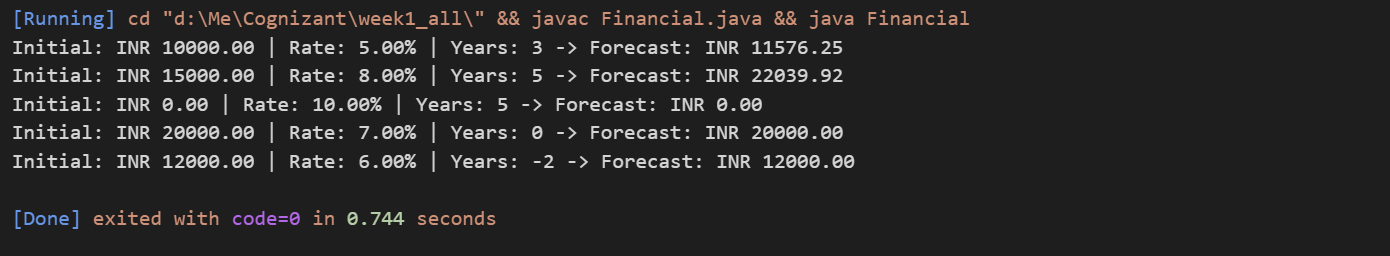
        double result = calculateFutureValue(value, rate, years);

        System.out.printf("Initial: INR %.2f | Rate: %.2f%% | Years: %d → Forecast: INR %.2f%n",

value, rate \* 100, years, result);    }

}

**Output :-**

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**Analysis**

Time complexity refers to the amount of computational time an algorithm takes to complete as a function of its input size. It helps us evaluate how efficiently an algorithm performs when scaled.

In the context of the financial forecasting tool, the input size is defined by the number of years for which the future value is to be predicted**.**

**Recursive Execution Breakdown**

Let’s assume years = n.

* On the **1st call**, it calculates value for year n
* On the **2nd call**, it calculates for year n - 1
* On the **nth call**, it calculates for year 1
* On the **(n + 1)th call**, the base case is reached and recursion stops

That means the function makes exactly **n recursive calls** before returning the final result.

**Final Time Complexity**

Since there is **one recursive call per year**, and each call does a constant-time operation (multiplication and subtraction), the overall time complexity is:

T(n)=O(n)​

This is **linear time complexity**, meaning the execution time grows proportionally with the number of years being forecasted.

**Optimization Techniques**

**Problem with Unoptimized Recursion**

Recursive algorithms, while often elegant and intuitive, can become inefficient or even problematic when:

* **The recursion depth is large** — leading to **stack overflow errors**
* **Overlapping subproblems** occur — causing **redundant calculations**
* **Excessive memory use** builds up in the call stack

In the context of our financial forecasting tool, if we are projecting future values for hundreds or thousands of years using pure recursion, each year introduces a new recursive call, and all intermediate values are stored until the base case is reached. This becomes increasingly costly in terms of memory and processing.

**Optimization Strategies**

**i. Switch to an Iterative Approach**

The **most efficient and recommended optimization** is to **rewrite the recursive logic iteratively**. In an iterative version:

* No call stack is used.
* Only one loop is needed.
* Memory usage remains constant, and performance improves.

**Example:**

public static double calculateFutureValueIterative(double currentValue, double annualRate, int years) {

for (int i = 0; i < years; i++) {

currentValue \*= (1 + annualRate);

}

return currentValue;

}

**Benefit:**

* Time complexity remains **O(n)**
* **Space complexity reduces from O(n) to O(1)** — no stack frames used

**ii. Use Mathematical Formulas (Closed-form)**

If you're only applying a compound interest-like formula, you can compute the result using a **closed-form equation** (non-recursive):

Future Value (FV)=Present Value (PV)×(1+r)^n

**Java Implementation:**

public static double calculateFutureValueMath(double currentValue, double annualRate, int years) {

return currentValue \* Math.pow(1 + annualRate, years);

}

**Benefit:**

* Time complexity becomes **O(1)** — constant time
* No iteration or recursion at all
* Very efficient and precise

**iii. Tail Recursion (Theoretical)**

Some programming languages (e.g., Scala, Haskell) support **tail call optimization**, where tail-recursive functions are compiled into loops. However, **Java does not support tail call optimization**, so this is **not a practical optimization** in Java.