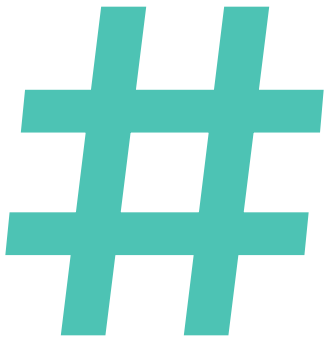
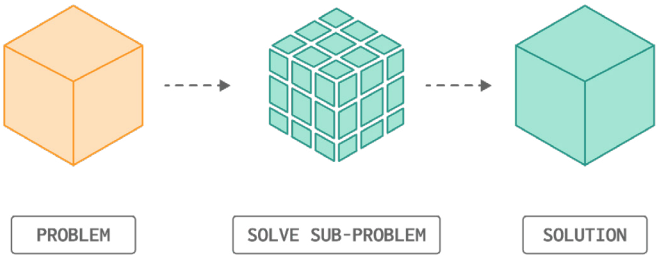


Dynamic Programming

Step 01 Dynamic Programming

Dynamic programming is an algorithm technique that is used to solve problems by breaking the problem into smaller subproblems then solve each subproblem once and store the solution to avoid redundancies, so we can have an optimal solution



Step 02 Why do we use dynamic programming

01 To optimize the time complexity of an algorithm from O(2^n) to O(n) or O(n^2)

02 By using dynamic programming we can find the number of ways to solve a problem and find an optimal solution to a problem.

Step 03 Steps to Solve Dynamic Programming Problems

01 Identify the subproblems

Break down the problem into smaller subproblems

02 Solve each subproblem once and store the solution

Once you solve the subproblem, store the solution to avoid redundancies using memoization or tabulation

03 Solve the main problem

Solve the main problem by using the solutions of the subproblems

Step 04 Dynamic Programming Types

01 Top-down approach (memoization)

This approach involves solving the problem recursively and storing the subproblems' solutions to avoid redundancies

02 Bottom-up approach (tabulation)

This approach involves solving the problem iteratively and storing the subproblems' solutions to avoid redundancies

Step 05 Example

Let's take the Fibonacci sequence as an example, Fibonacci sequence is a series of numbers in which the next number is the sum of the two previous numbers subtracting the first number by

- **-1** and the second number by **-2, F n-1 + F n-2.**
- Fibonacci sequence are **1, 1, 2, 3, 5, 8, 13, 21, 34,...**
- Example: The Fibonacci sequence of **6 is 3 + 5 = 8**

01 Break down the problem into smaller subproblems

02 Solve each subproblem once and store the solution

03 Solve the main problem

Step 06 Implementation

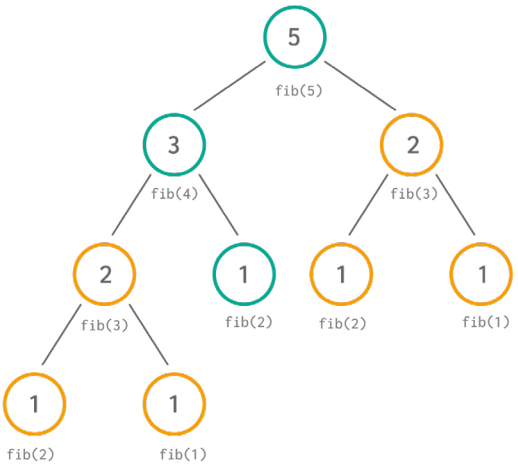
Let's solve the Fibonacci sequence using recursion, and then we will optimize the solution using dynamic programming

```
01  class Main {
02      public static void main(String[] args) {
03
04        System.out.println(fibonacci(6));
05      }
06
07      public static int fibonacci(int number) {
08          if(number <= 2) {
09            return 1;
10          } else {
11            // Fibonacci formula  fib(n) = fib(n-1) + fib(n-2)
12            return fibonacci(number - 1) + fibonacci(number - 2);
13          }
14        }
15    }
```

OUTPUT

```
8
```

Although the output is correct, the time complexity of the algorithm is O(2^n) which is not optimal, if we want to calculate the Fibonacci sequence of 50, it will take a long time to get the result



Notice that we have redundancies in the solution, for example, the Fibonacci sequence of 3 is calculated twice, and the Fibonacci sequence of 2 is calculated three times.

Dynamic programming has two techniques to solve the problem.

01 First technique is top-down (memoization)

In this technique, we solve the problem recursively and store the solution of the subproblems in a map.

> **NOTE**
> map is a data structure that holds key-value pairs, the key is the Fibonacci number and the valueis is the result.

```java
import java.util.HashMap;
import java.util.Map;
class Main {
  // memo will hold the solution of the subproblems the key is the Fibonacci
   number and the value is the result.
  private static Map<Integer, Integer> memo = new HashMap<>();


    public static void main(String[] args) {
        System.out.println(fibonacci(6)); // Example usage
    }

    public static int fibonacci(int number) {
      // Check if the number is already solved
        if (memo.containsKey(number)) {
            return memo.get(number);
        }

        int result;
        if (number <= 2) {
            result = 1;
        } else {
            result = fibonacci(number - 1) + fibonacci(number - 2);
        }

        // Save the result in the memo
        memo.put(number, result);
        return result;
    }

}
```

OUTPUT

```
8
```

02 Second technique is Bottom-Up (Tabulation)

In this technique, we solve the problem iteratively and store the solution of the subproblems in an array

```java
class Main {

    public static void main(String[] args) {
        System.out.println(fibonacci(6)); // Example usage
    }

    public static int fibonacci(int number) {
      if (number <= 2) {
          return 1;
      }

      // store the solution to the subproblem in an array
      int[] fib = new int[number + 1];
      fib[1] = fib[2] = 1;

      for (int i = 3; i <= number; i++) {
          fib[i] = fib[i - 1] + fib[i - 2];
      }

      return fib[number];
  }
}
```

OUTPUT

```
8
```

Remember to use the memoization or tabulation technique to store the solution of the sub-problems to avoid redundancies.

memoization uses recursion and linked list to store the solution of the subproblems, and tabulation uses iteration and array to store the solution of the subproblems.

> **NOTE**
> memoization is a Latin word that means remembering