Matrix Multiplication

Aim:-

Multiply Two Matrices using Divide and Conquer Approach

Theory :-

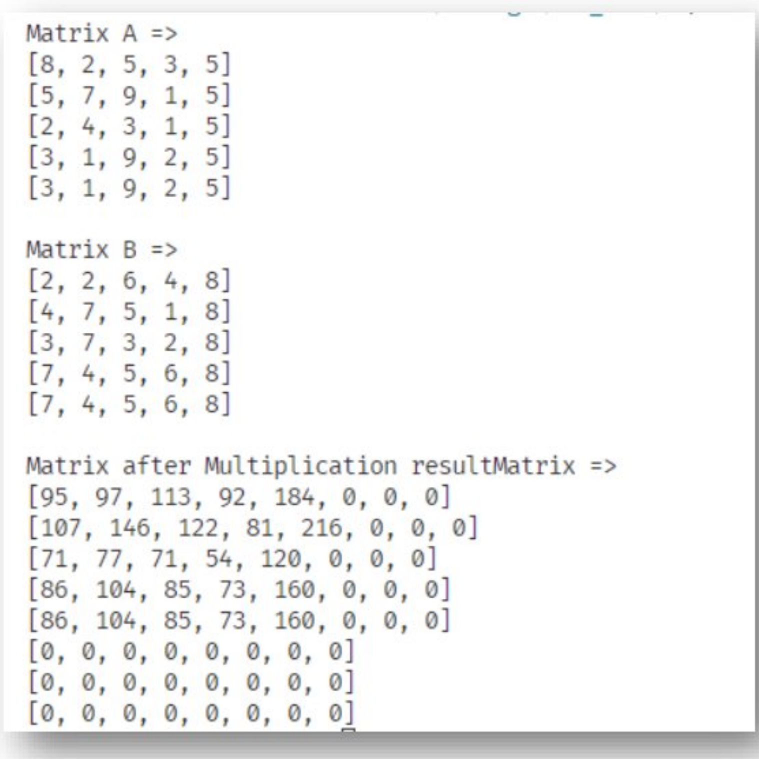
The divide-and-conquer approach works by dividing the input matrices into four sub-matrices and recursively applying the algorithm to these sub-matrices. The resulting sub-products are then combined using a set of addition and subtraction operations to obtain the final product. This approach can be further optimized by using the Strassen algorithm, which reduces the number of multiplications required for each sub-matrix.

The divide-and-conquer approach to matrix multiplication has many applications in fields such as scientific computing, computer vision, and machine learning. It is especially useful when working with large matrices, where traditional algorithms can be prohibitively slow.

Code :-

```java
import java.util.Arrays;

public class MMusingDandC9 {
    public static void main(String[] args) throws IllegalArgumentException {
        // Test Case
        int[][] a = {
                { 8, 2, 5, 3, 5 },
                { 5, 7, 9, 1, 5 },
                { 2, 4, 3, 1, 5 },
                { 3, 1, 9, 2, 5 },
                { 3, 1, 9, 2, 5 }
        };
        int[][] b = {
                { 2, 2, 6, 4, 8 },
                { 4, 7, 5, 1, 8 },
                { 3, 7, 3, 2, 8 },
                { 7, 4, 5, 6, 8 },
                { 7, 4, 5, 6, 8 }
        };
        System.out.println("Matrix A =>");
        for (int i = 0; i < a.length; i++) {
            System.out.println(Arrays.toString(a[i]));
        }
        System.out.println();
        System.out.println("Matrix B =>");
        for (int i = 0; i < b.length; i++) {
            System.out.println(Arrays.toString(b[i]));
        }
        System.out.println();
        System.out.println("Matrix after Multiplication resultMatrix =>");
        int[][] resultMatrix = matrixMultiply(a, b);
        for (int i = 0; i < resultMatrix.length; i++) {
            System.out.println(Arrays.toString(resultMatrix[i]));
        }
    }

    public static int[][] matrixMultiply(int[][] A, int[][] B) {
        int l1 = A.length, h1 = A[0].length, l2 = B.length, h2 = B[0].length;
        if (h1 != l2) {
            throw new IllegalArgumentException("Matrices cannot be multiplied");
        }
        int max = Math.max(Math.max(l1, h1), Math.max(l2, h2));
        float next2 = (float) (Math.log(max) / Math.log(2));
        int next = (int) Math.ceil(next2);
        int n = (int) Math.pow(2, next);
        int[][] a = new int[n][n];
        int[][] b = new int[n][n];

        // Doing padding
        for (int i = 0; i < l1; i++) {
            for (int j = 0; j < h1; j++) {
                a[i][j] = A[i][j];
            }
        }
        for (int i = 0; i < n; i++) {
            for (int j = 0; j < n; j++) {
                if (i < l2 && j < h2)
                    b[i][j] = B[i][j];
                else
                    b[i][j] = 0;
            }
        }
        return matrixMultiplyDivideConquer(a, b); // Calling this function after
padding so to avoid this repetition in recursive calls
    }

    public static int[][] matrixMultiplyDivideConquer(int[][] A, int[][] B) {
        int n = A.length;

        // If the matrices are 1x1, just do a simple multiplication
        if (n == 1) {
            int[][] C = new int[1][1];
            C[0][0] = A[0][0] * B[0][0];
            return C;
        }

        // Split matrices into quarters
        int size = n / 2;
        int[][] a11 = new int[size][size];
        int[][] a12 = new int[size][size];
        int[][] a21 = new int[size][size];
        int[][] a22 = new int[size][size];
        int[][] b11 = new int[size][size];
        int[][] b12 = new int[size][size];
        int[][] b21 = new int[size][size];
        int[][] b22 = new int[size][size];

        for (int i = 0; i < size; i++) {
            for (int j = 0; j < size; j++) {
                a11[i][j] = A[i][j];
                a12[i][j] = A[i][j + size];
                a21[i][j] = A[i + size][j];
                a22[i][j] = A[i + size][j + size];
                b11[i][j] = B[i][j];
                b12[i][j] = B[i][j + size];
                b21[i][j] = B[i + size][j];
                b22[i][j] = B[i + size][j + size];
            }
        }
        // Recursively compute products
        int[][] p1 = matrixMultiplyDivideConquer(a11, b11);
        int[][] p2 = matrixMultiplyDivideConquer(a12, b21);
        int[][] p3 = matrixMultiplyDivideConquer(a11, b12);
        int[][] p4 = matrixMultiplyDivideConquer(a12, b22);
        int[][] p5 = matrixMultiplyDivideConquer(a21, b11);
        int[][] p6 = matrixMultiplyDivideConquer(a22, b21);
        int[][] p7 = matrixMultiplyDivideConquer(a21, b12);
        int[][] p8 = matrixMultiplyDivideConquer(a22, b22);

        // Compute result matrix
        int[][] C = new int[n][n];

        for (int i = 0; i < size; i++) {
            for (int j = 0; j < size; j++) {
                C[i][j] = p1[i][j] + p2[i][j];
                C[i][j + size] = p3[i][j] + p4[i][j];
                C[i + size][j] = p5[i][j] + p6[i][j];
                C[i + size][j + size] = p7[i][j] + p8[i][j];
            }
        }

        return C;
    }

}
```

Output :-



```
Matrix A =>
[8, 2, 5, 3, 5]
[5, 7, 9, 1, 5]
[2, 4, 3, 1, 5]
[3, 1, 9, 2, 5]
[3, 1, 9, 2, 5]

Matrix B =>
[2, 2, 6, 4, 8]
[4, 7, 5, 1, 8]
[3, 7, 3, 2, 8]
[7, 4, 5, 6, 8]
[7, 4, 5, 6, 8]

Matrix after Multiplication resultMatrix =>
[95, 97, 113, 92, 184, 0, 0, 0]
[107, 146, 122, 81, 216, 0, 0, 0]
[71, 77, 71, 54, 120, 0, 0, 0]
[86, 104, 85, 73, 160, 0, 0, 0]
[86, 104, 85, 73, 160, 0, 0, 0]
[0, 0, 0, 0, 0, 0, 0, 0]
[0, 0, 0, 0, 0, 0, 0, 0]
[0, 0, 0, 0, 0, 0, 0, 0]
```