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Subject	Design and Analysis of Algorithms (DAA)
Experiment No.	5
Aim	To implement Matrix Chain Multiplication.
Code:	

```c
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
#include <limits.h>

#define NUM_MATRICES 10

// Function to allocate memory for a 2D matrix
int** allocateMatrix(int rows, int cols) {
    int **matrix = (int **)malloc(rows * sizeof(int *));
    for (int i = 0; i < rows; i++) {
        matrix[i] = (int *)malloc(cols * sizeof(int));
    }
    return matrix;
}

// Function to free memory for a 2D matrix
void freeMatrix(int **matrix, int rows) {
    for (int i = 0; i < rows; i++) {
        free(matrix[i]);
    }
    free(matrix);
}

// Function to generate random matrices
void generateRandomMatrices(int ***matrices, int *dims) {
    for (int i = 0; i < NUM_MATRICES; i++) {
        int rows = dims[i];
```

	(code below)

```
        int cols = dims[i + 1];
        matrices[i] = allocateMatrix(rows, cols);
        for (int row = 0; row < rows; row++) {
            for (int col = 0; col < cols; col++) {
                matrices[i][row][col] = rand() % 2; // Random
values between 0 and 1
            }
        }
    }
}

// Function to perform Matrix Chain Multiplication using
dynamic programming
void matrixChainMultiplication(int dims[], int n, int **m, int
**c) {
    for (int i = 1; i <= n; i++) {
        m[i][i] = 0;
    }

    for (int len = 2; len <= n; len++) {
        for (int i = 1; i <= n - len + 1; i++) {
            int j = i + len - 1;
            m[i][j] = INT_MAX;
            for (int k = i; k < j; k++) {
                int cost = m[i][k] + m[k+1][j] + dims[i-
1]*dims[k]*dims[j];
                if (cost < m[i][j]) {
                    m[i][j] = cost;
                    c[i][j] = k;
                }
            }
        }
    }
}

int main() {
    srand(time(NULL));
```

```
    // Generate random dimensions for matrices
    int dims[NUM_MATRICES + 1]; // +1 to include the
dimensions of result matrix
    printf("Random Dimensions for Matrices:\n");
    for (int i = 0; i <= NUM_MATRICES; i++) {
        dims[i] = rand() % 32 + 15; // Random dimensions
between 15 and 46
        printf("M%d: %2d x %2d\n", i, dims[i-1], dims[i]);
    }

    // Generate random matrices
    int ***matrices = (int ***)malloc(NUM_MATRICES *
sizeof(int **));
    generateRandomMatrices(matrices, dims);

    // Allocate memory for storing optimal solutions and
parenthesizations
    int **m = allocateMatrix(NUM_MATRICES + 1, NUM_MATRICES +
1);
    int **c = allocateMatrix(NUM_MATRICES + 1, NUM_MATRICES +
1);

    // Perform Matrix Chain Multiplication and measure time
    clock_t start = clock();
    matrixChainMultiplication(dims, NUM_MATRICES, m, c);
    clock_t end = clock();
    double duration_mcm = ((double)(end - start)) /
CLOCKS_PER_SEC;

    // Print optimal solutions
    printf("\nOptimal Solutions (No. of Multiplications):\n");
    for (int i = 1; i <= NUM_MATRICES; i++) {
        for (int j = 1; j <= NUM_MATRICES; j++) {
            printf("%6d", m[i][j]);
        }
        printf("\n");
```

```
    }
    // Print time for Matrix Chain Multiplication
    printf("\nTime for Matrix Chain Multiplication: %.6f
seconds\n", duration_mcm);

    // Print the cost matrix and the k matrix
    printf("\nCost Matrix:\n");
    for (int i = 1; i <= NUM_MATRICES; i++) {
        for (int j = 1; j <= NUM_MATRICES; j++) {
            printf("%6d", m[i][j]);
        }
        printf("\n");
    }

    printf("\nK Matrix:\n");
    for (int i = 1; i <= NUM_MATRICES; i++) {
        for (int j = 1; j <= NUM_MATRICES; j++) {
            printf("%6d", c[i][j]);
        }
        printf("\n");
    }

    // Free allocated memory for matrices
    for (int i = 0; i < NUM_MATRICES; i++) {
        freeMatrix(matrices[i], dims[i]);
    }
    free(matrices);

    // Free allocated memory for optimal solutions and
parenthesizations
    freeMatrix(m, NUM_MATRICES + 1);
    freeMatrix(c, NUM_MATRICES + 1);

    return 0;
}
```

Output

```
PROBLEMS    OUTPUT    DEBUG CONSOLE    TERMINAL    PORTS    GITLENS    SEARCH ERROR

PS D:\Manish\SPIT\4th SEM\DAA\Exp5> cd 'd:\Manish\SPIT\4th SEM\DAA\Exp5\output'
PS D:\Manish\SPIT\4th SEM\DAA\Exp5\output> & .\'mcm.exe'
Random Dimensions for Matrices:
M0:  8 x 35
M1: 35 x 33
M2: 33 x 21
M3: 21 x 34
M4: 34 x 16
M5: 16 x 23
M6: 23 x 26
M7: 26 x 28
M8: 28 x 34
M9: 34 x 29
M10: 29 x 25

Optimal Solutions (No. of Multiplications):
     0 24255 49245 40992 53872 65120 77888 96480109456118816
8586656     0 23562 22512 34656 45808 58512 76912 90048 99536
8586656     0     0 11424 19152 29728 42048 59296 73392 83648
8586656     0     0     0 12512 23712 36448 54944 68000 77424
8586656     0     0     0     0  9568 21216 36448 52224 63824
8586656     0     0     0     0     0 16744 38640 61318 77993
8586656     0     0     0     0     0     0 24752 48720 66108
8586656     0     0     0     0     0     0     0 27608 47908
8586656     0     0     0     0     0     0     0     0 24650
8586656     0     0     0     0     0     0     0     0     0

Time for Matrix Chain Multiplication: 0.000000 seconds
```

```
Cost Matrix:
     0 24255 49245 40992 53872 65120 77888 96480109456118816
8586656     0 23562 22512 34656 45808 58512 76912 90048 99536
8586656     0     0 11424 19152 29728 42048 59296 73392 83648
8586656     0     0     0 12512 23712 36448 54944 68000 77424
8586656     0     0     0     0  9568 21216 36448 52224 63824
8586656     0     0     0     0     0 16744 38640 61318 77993
8586656     0     0     0     0     0     0 24752 48720 66108
8586656     0     0     0     0     0     0     0 27608 47908
8586656     0     0     0     0     0     0     0     0 24650
8586656     0     0     0     0     0     0     0     0     0

K Matrix:
8586656     1     2     1     4     4     4     4     4     4
8586656     0     2     2     4     4     4     4     4     4
     0     0     0     3     4     4     4     4     4     4
     0     0     0     0     4     4     4     4     4     4
     0     0     0     0     0     5     6     7     8     9
     0     0     0     0     0     0     6     7     8     9
     0     0     0     0     0     0     0     7     7     7
     0     0     0     0     0     0     0     0     8     9
     0     0     0     0     0     0     0     0     0     9
     0     0     0     0     0     0     0     0     0     0
PS D:\Manish\SPIT\4th SEM\DAA\Exp5\output>
```

Pseudo Code

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Experiment No:- 5

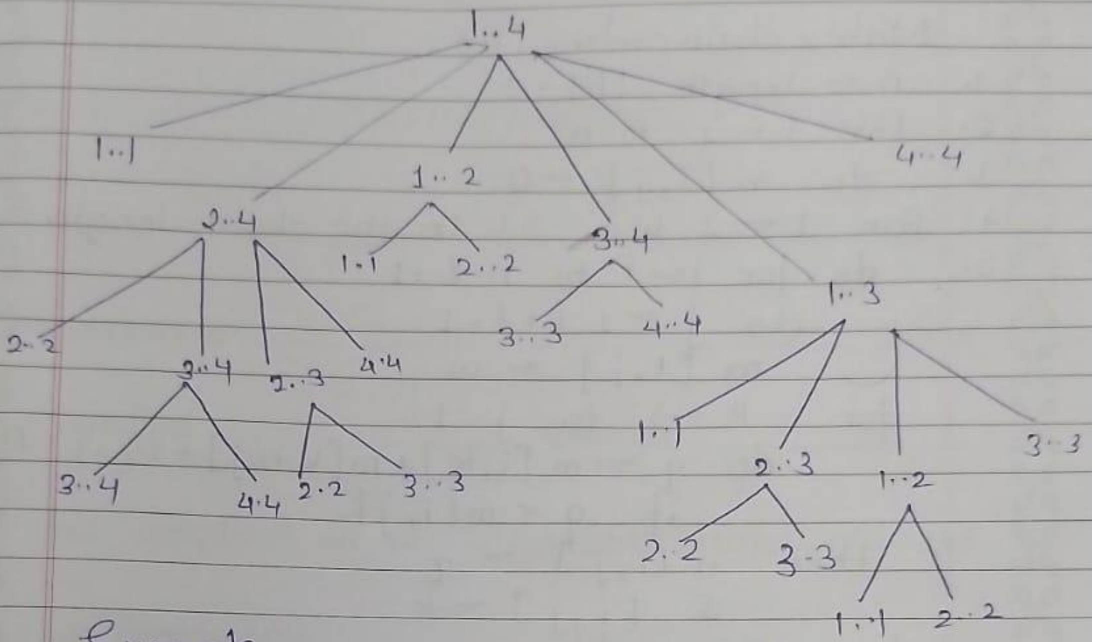
1. Pseudo Code

```
Matrix_chain_order (P)
1.  n ← length [P] - 1
2.  For i ← 1 to n
3.    do m[i, j] ← 0
4.  For L ← 2 to n    ▷ L in the chain length
5.    do for i ← 1 to n-l+1
           do j ← i+l-1
              m[i, j] ← ∞
      for    k ← i to j-1
             do q ← m[i, k] + m[k+1, j] + Pi-1 Pk Pj
                if q < m[i, j]
        then    m[i, j] ← q
                s [i, j] ← k
return m and s
```

$$m[i,j] = \begin{cases} 0 & \text{if } i=j \\ \min\limits_{i \le k < j} \left\{ m[i,k] + m[k+1,j] + p_{i-1} p_k p_j \right\} & \text{if } (i<j) \end{cases}$$

- Below is the recursion tree for recursive approach:-

~~Example~~



* Example

P_0	P_1	P_2	P_3	P_4
5	6	4	2	3

A_1	A_2	A_3	A_4
5×6	6×4	4×2	2×3

m	1	2	3	4
1	0	120	108	54
2	0	0	48	84
3	0	0	0	24
4	0	0	0	0

s	1	2	3	4
1	0	1	1	3
2	0	0	2	3
3	0	0	0	3
4	0	0	0	0

$$m[1,2] = m[1,1] + m[2,2] + P_0 \cdot P_1 \cdot P_2$$
$$= 0 + 0 + 5 \cdot 6 \cdot 4$$
$$= \underline{\underline{120}}$$

$$m[2,3] = m[2,2] + m[3,3] + P_1 \cdot P_2 \cdot P_3$$
$$= 0 + 0 + 6 \cdot 4 \cdot 2$$
$$= \underline{\underline{48}}$$

$$m[3,4] = m[3,3] + m[4,4] + P_2 \cdot P_3 \cdot P_4$$
$$= 0 + 0 + 4 \cdot 2 \cdot 3$$
$$= \underline{\underline{24}}$$

$$m[1,3] = m[1,1] + m[2,3] + P_0 \cdot P_1 \cdot P_3$$
$$= 0 + 48 + 5 \cdot 6 \cdot 2$$
$$= \underline{\underline{108}}$$

$$m[1,3] = m[1,2] + m[3,3] + P_0 \cdot P_2 \cdot P_3$$
$$= 120 + 0 + 5 \cdot 4 \cdot 2$$
$$= \underline{\underline{160}}$$

$m[2,4] = A_2 \cdot (A_3 \cdot A_4) \qquad (A_2 \cdot A_3) \cdot A_4$

$m[2,4] = m[2,2] + m[3,4] + P_1 \cdot P_2 \cdot P_4$
$= 0 + 24 + 6 \cdot 4 \cdot 3$
$= \underline{96}$

$m[2,4] = m[2,3] + m[4,4] + P_1 \cdot P_3 \cdot P_4$
$= 48 + 0 + 6 \cdot 2 \cdot 3$
$= \underline{84}$

$m[1,4] = m[1,1] + m[2,4] + P_0 \cdot P_1 \cdot P_4$
$= 0 + 84 + 5 \cdot 6 \cdot 3$
$= \underline{174}$

$m[1,4] = m[1,2] + m[3,4] + P_0 \cdot P_2 \cdot P_4$
$= 120 + 24 + 5 \cdot 4 \cdot 3$
$= \underline{204}$

$m[1,4] = m[1,3] + m[4,4] + P_0 \cdot P_3 \cdot P_4$
$= 24 + 0 + 5 \cdot 2 \cdot 3$
$= \underline{54}$

Conclusion	Hence, by completing this experiment I came to know about implementation of Matrix Chain Multiplication.