Matrix Multiplication

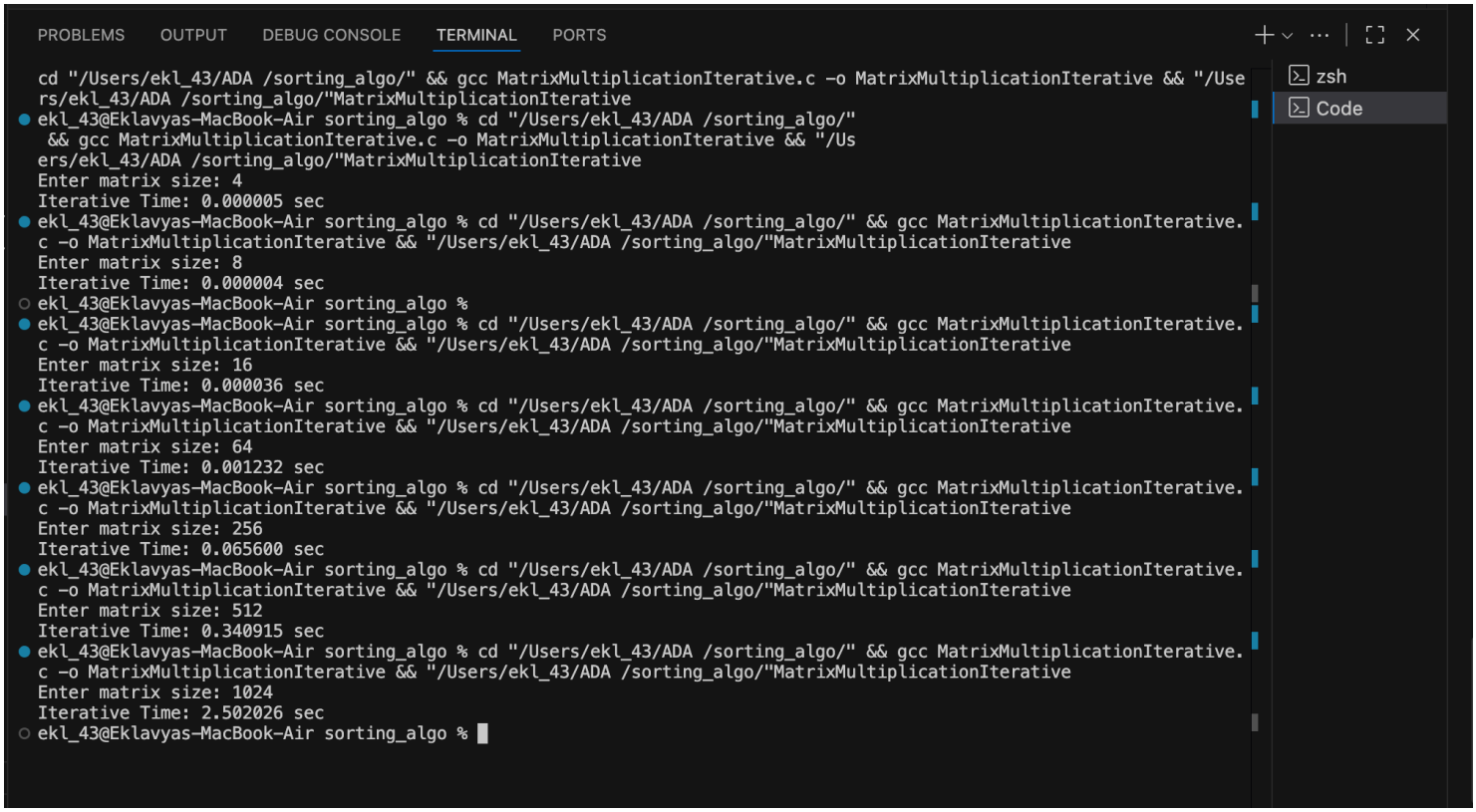
3(a) Write a program in C language to multiply two square matrices using the iterative approach. Compare the execution time for different matrix sizes.

C CODE:

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
// Allocate n×n matrix
int **alloc_matrix(int n) {
int **mat = (int **)malloc(n * sizeof(int *));
for (int i = 0; i < n; i++)
mat[i] = (int *)malloc(n * sizeof(int));
return mat;
}
void free_matrix(int **mat, int n) {
for (int i = 0; i < n; i++) free(mat[i]);
free(mat);
}
void fill_matrix(int **mat, int n) {
for (int i = 0; i < n; i++)
for (int j = 0; j < n; j++)
mat[i][j] = rand() % 10;
}
// Iterative multiplication
void multiply_iterative(int **A, int **B, int **C, int n) {
for (int i = 0; i < n; i++)
for (int j = 0; j < n; j++) {
C[i][j] = 0;
for (int k = 0; k < n; k++)
C[i][j] += A[i][k] * B[k][j];
}
}
int main() {
srand(time(NULL));
int n;
printf("Enter matrix size: ");
scanf("%d", &n);
int **A = alloc_matrix(n);
int **B = alloc_matrix(n);
int **C = alloc_matrix(n);fill_matrix(A, n);
fill_matrix(B, n);
clock_t start = clock();
multiply_iterative(A, B, C, n);
clock_t end = clock();
printf("Iterative Time: %f sec\n", (double)(end - start) / CLOCKS_PER_SEC);
free_matrix(A, n);
free_matrix(B, n);
```

```
free_matrix(C, n);
return 0;
}
```

Output:



3(b) Write a program in C language to multiply two square matrices using the . Compare the execution time for different matrix sizes.

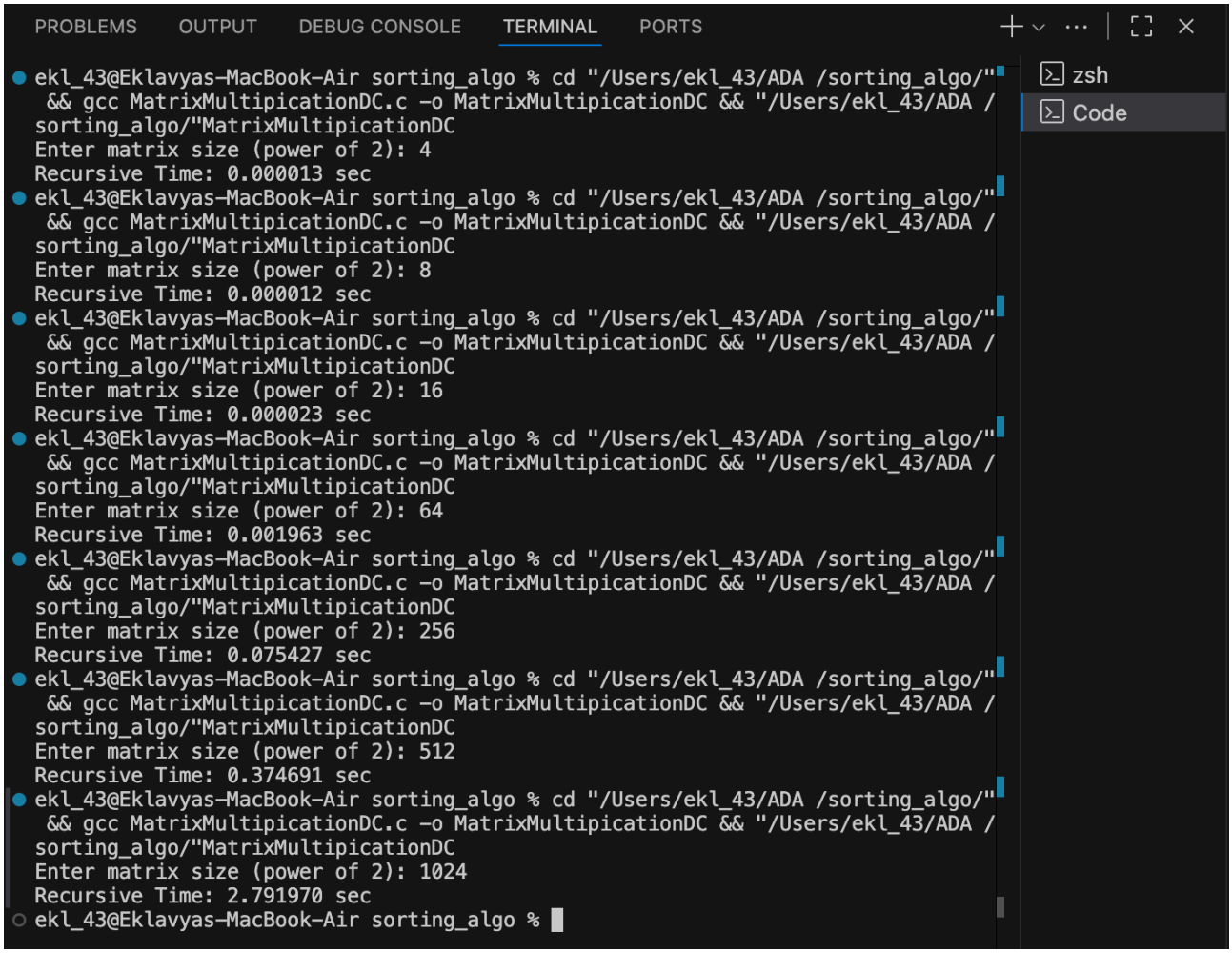
C CODE:

```
#include <stdio.h>
#include <stdlib.h>
#include <time.h>
// Allocate matrix
int **alloc_matrix(int n) {
int **mat = (int **)malloc(n * sizeof(int *));
for (int i = 0; i < n; i++)
mat[i] = (int *)malloc(n * sizeof(int));
return mat;
}
void free_matrix(int **mat, int n) {
for (int i = 0; i < n; i++) free(mat[i]);
free(mat);
```

```
}
void fill_matrix(int **mat, int n) {
for (int i = 0; i < n; i++)
for (int j = 0; j < n; j++)
mat[i][j] = rand() % 10;
}
// Recursive utility
void multiply_recursive_util(int **A, int **B, int **C, int n,
int a_row, int a_col,
int b_row, int b_col,
int c_row, int c_col) {
if (n == 1) {
return;
C[c_row][c_col] += A[a_row][a_col] * B[b_row][b_col];
}
int half = n / 2;
multiply_recursive_util(A, B, C, half, a_row, a_col, b_row, b_col, c_row, c_col);
multiply_recursive_util(A, B, C, half, a_row, a_col + half, b_row + half, b_col,
c_row, c_col);multiply_recursive_util(A, B, C, half, a_row, a_col, b_row, b_col +
half, c_row,
c_col + half);
multiply_recursive_util(A, B, C, half, a_row, a_col + half, b_row + half, b_col +
half, c_row, c_col + half);
multiply_recursive_util(A, B, C, half, a_row + half, a_col, b_row, b_col, c_row +
half, c_col);
multiply_recursive_util(A, B, C, half, a_row + half, a_col + half, b_row + half,
b_col, c_row + half, c_col);
multiply_recursive_util(A, B, C, half, a_row + half, a_col, b_row, b_col + half,
c_row + half, c_col + half);
multiply_recursive_util(A, B, C, half, a_row + half, a_col + half, b_row + half,
b_col + half, c_row + half, c_col + half);
}
// Wrapper
void multiply_recursive(int **A, int **B, int **C, int n) {
for (int i = 0; i < n; i++)
for (int j = 0; j < n; j++)
C[i][j] = 0;
multiply_recursive_util(A, B, C, n, 0, 0, 0, 0, 0, 0);
}
int main() {
srand(time(NULL));
int n;
printf("Enter matrix size (power of 2): ");
scanf("%d", &n);
int **A = alloc_matrix(n);
int **B = alloc_matrix(n);
int **C = alloc_matrix(n);
fill_matrix(A, n);
```

```
fill_matrix(B, n);
clock_t start = clock();
multiply_recursive(A, B, C, n);
clock_t end = clock();
printf("Recursive Time: %f sec\n", (double)(end - start) / CLOCKS_PER_SEC);
free_matrix(A, n);
free_matrix(B, n);
free_matrix(C, n);
return 0;
}
```

OUTPUT:



3(c) Given two square matrices A and B of size n × n (n is a power of 2), write a C code to multiply them using , which reduces the number of recursive multiplications from 8 to 7 by introducing additional addition/subtraction operations. Compare the execution time for different matrix sizes.

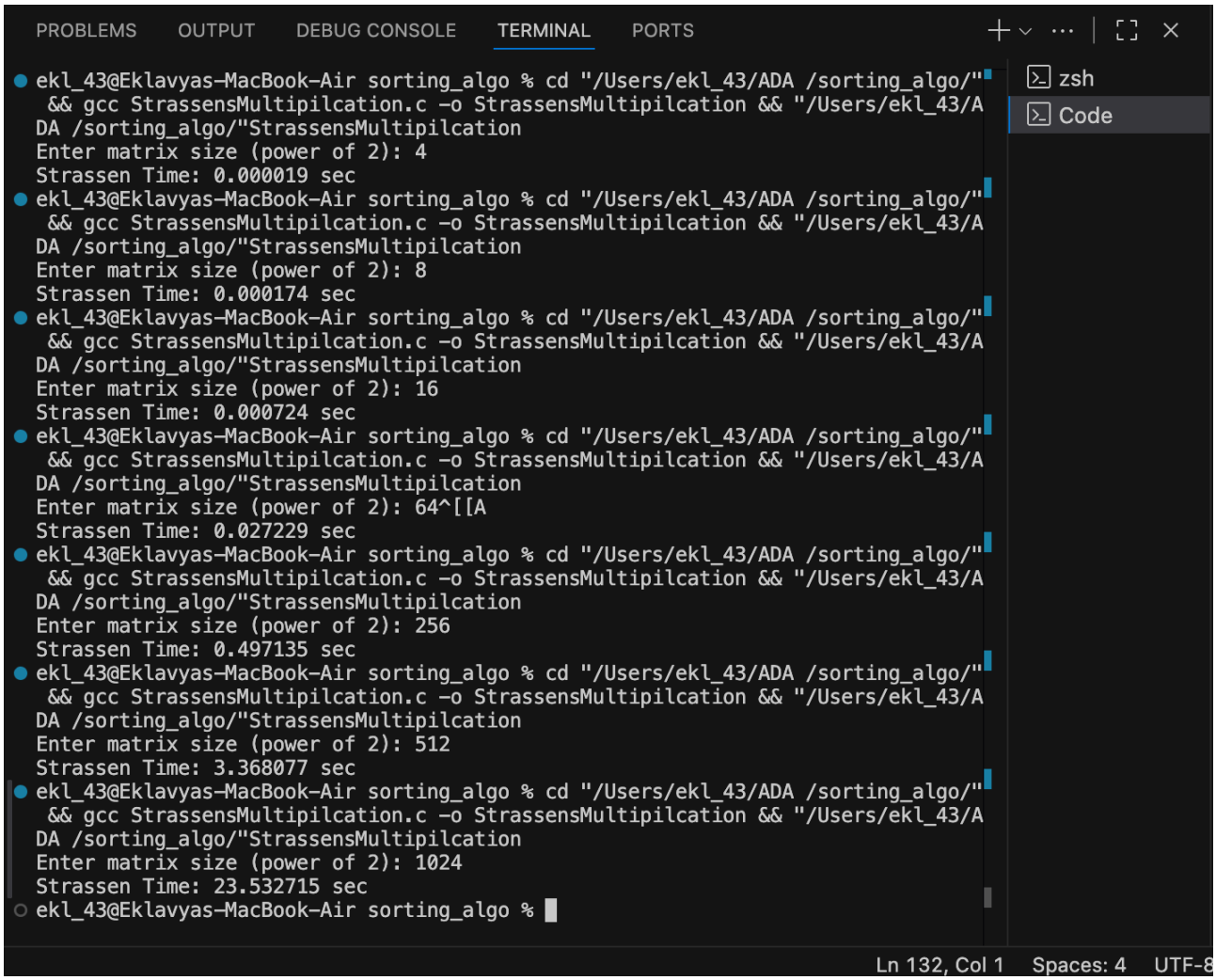
C CODE:

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

// --- Helpers ---
int **alloc_matrix(int n) {
    int **mat = (int **)malloc(n * sizeof(int *));
    for (int i = 0; i < n; i++)
        mat[i] = (int *)malloc(n * sizeof(int));
    return mat;
}
void free_matrix(int **mat, int n) {
    for (int i = 0; i < n; i++) free(mat[i]);
    free(mat);
}
void fill_matrix(int **mat, int n) {
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            mat[i][j] = rand() % 10;
}
void add_matrix(int **A, int **B, int **C, int n) {
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            C[i][j] = A[i][j] + B[i][j];
}
void sub_matrix(int **A, int **B, int **C, int n) {
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++)
            C[i][j] = A[i][j] - B[i][j];
}
void multiply_iterative(int **A, int **B, int **C, int n) {
    for (int i = 0; i < n; i++)
        for (int j = 0; j < n; j++) {
            C[i][j] = 0;
            for (int k = 0; k < n; k++)
                C[i][j] += A[i][k] * B[k][j];
        }
}

// --- Strassen Algorithm ---
void strassen(int **A, int **B, int **C, int n) {
    if (n <= 2) { // base case
        multiply_iterative(A, B, C, n);
        return;
    }
    int k = n / 2;
    int **A11 = alloc_matrix(k), **A12 = alloc_matrix(k),
        **A21 = alloc_matrix(k), **A22 = alloc_matrix(k);
    int **B11 = alloc_matrix(k), **B12 = alloc_matrix(k),
```

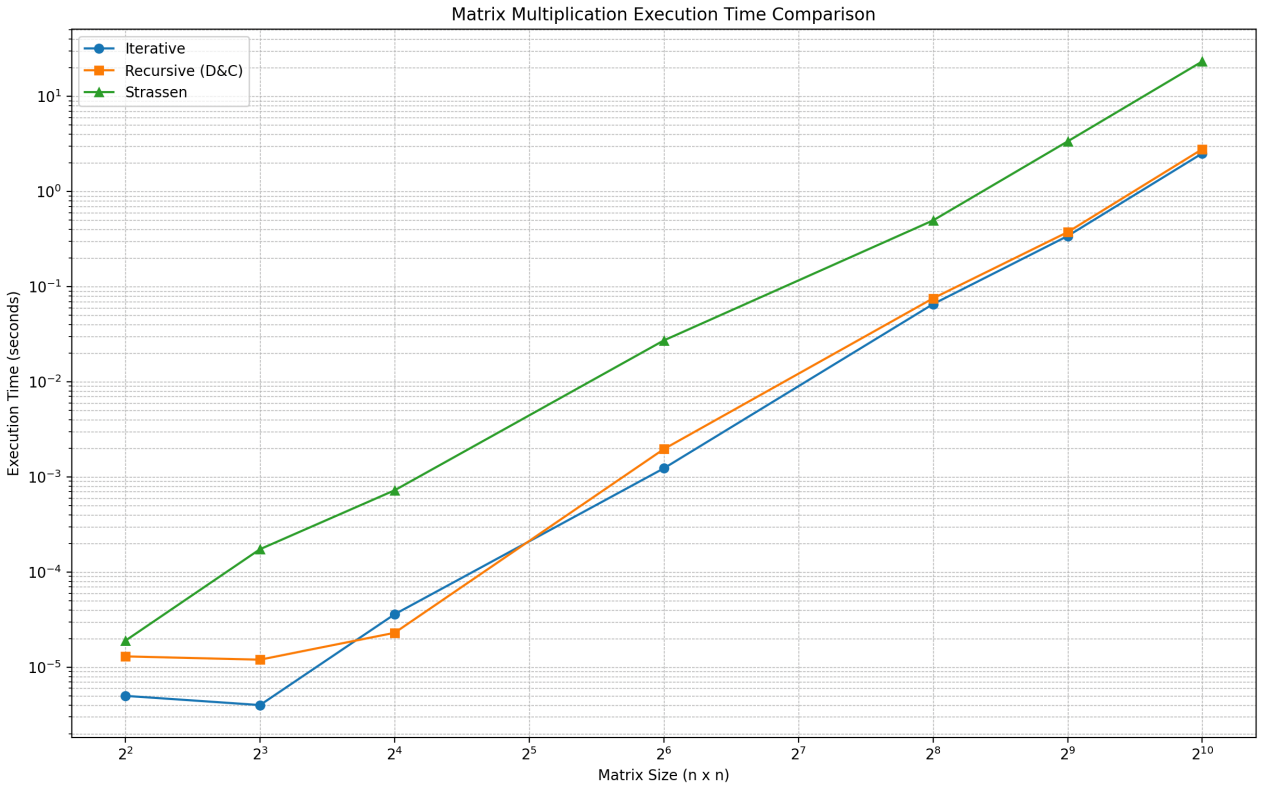
```
    **B21 = alloc_matrix(k), **B22 = alloc_matrix(k);
  int **C11 = alloc_matrix(k), **C12 = alloc_matrix(k),
    **C21 = alloc_matrix(k), **C22 = alloc_matrix(k);
  int **M1 = alloc_matrix(k), **M2 = alloc_matrix(k), **M3 = alloc_matrix(k),
    **M4 = alloc_matrix(k), **M5 = alloc_matrix(k), **M6 = alloc_matrix(k),
    **M7 = alloc_matrix(k);
  int **T1 = alloc_matrix(k), **T2 = alloc_matrix(k);

  // Split matrices
  for (int i = 0; i < k; i++) {
    for (int j = 0; j < k; j++) {
      A11[i][j] = A[i][j];
      A12[i][j] = A[i][j + k];
      A21[i][j] = A[i + k][j];
      A22[i][j] = A[i + k][j + k];
      B11[i][j] = B[i][j];
      B12[i][j] = B[i][j + k];
      B21[i][j] = B[i + k][j];
      B22[i][j] = B[i + k][j + k];
    }
  }

  // M1..M7
  add_matrix(A11, A22, T1, k); add_matrix(B11, B22, T2, k); strassen(T1, T2, M1, k);
  add_matrix(A21, A22, T1, k); strassen(T1, B11, M2, k);
  sub_matrix(B12, B22, T2, k); strassen(A11, T2, M3, k);
  sub_matrix(B21, B11, T2, k); strassen(A22, T2, M4, k);
  add_matrix(A11, A12, T1, k); strassen(T1, B22, M5, k);
  sub_matrix(A21, A11, T1, k); add_matrix(B11, B12, T2, k); strassen(T1, T2, M6, k);
  sub_matrix(A12, A22, T1, k); add_matrix(B21, B22, T2, k); strassen(T1, T2, M7, k);

  // C11..C22
  for (int i = 0; i < k; i++) {
    for (int j = 0; j < k; j++) {
      C11[i][j] = M1[i][j] + M4[i][j] - M5[i][j] + M7[i][j];
      C12[i][j] = M3[i][j] + M5[i][j];
      C21[i][j] = M2[i][j] + M4[i][j];
      C22[i][j] = M1[i][j] - M2[i][j] + M3[i][j] + M6[i][j];
    }
  }

  // Merge result
  for (int i = 0; i < k; i++) {
    for (int j = 0; j < k; j++) {
      C[i][j] = C11[i][j];
      C[i][j + k] = C12[i][j];
      C[i + k][j] = C21[i][j];
      C[i + k][j + k] = C22[i][j];
    }
  }

  // Free memory
  free_matrix(A11, k); free_matrix(A12, k); free_matrix(A21, k); free_matrix(A22, k);
  free_matrix(B11, k); free_matrix(B12, k); free_matrix(B21, k); free_matrix(B22, k);
  free_matrix(C11, k); free_matrix(C12, k); free_matrix(C21, k); free_matrix(C22, k);
  free_matrix(M1, k); free_matrix(M2, k); free_matrix(M3, k); free_matrix(M4, k);
  free_matrix(M5, k); free_matrix(M6, k); free_matrix(M7, k);
  free_matrix(T1, k); free_matrix(T2, k);
}
```

```
int main() {
    srand(time(NULL));
    int n;
    printf("Enter matrix size (power of 2): ");
    scanf("%d", &n);

    int **A = alloc_matrix(n);
    int **B = alloc_matrix(n);
    int **C = alloc_matrix(n);

    fill_matrix(A, n);
    fill_matrix(B, n);

    clock_t start = clock();
    strassen(A, B, C, n);
    clock_t end = clock();

    printf("Strassen Time: %f sec\n", (double)(end - start) / CLOCKS_PER_SEC);

    free_matrix(A, n); free_matrix(B, n); free_matrix(C, n);
    return 0;
}
```

OUTPUT:



Matrix Size	Iterative (sec)	Recursive (sec)	Strassen (sec)
4.0	5e-06	1.3e-05	1.9e-05
8.0	4e-06	1.2e-05	0.000174
16.0	3.6e-05	2.3e-05	0.000724
64.0	0.001232	0.001963	0.027229
256.0	0.0656	0.075427	0.497135
512.0	0.340915	0.374691	3.368077
1024.0	2.520226	2.79197	23.32715



Time Complexity in Practice: Iterative vs. Recursive vs. Strassen

Iterative Method

• Time Complexity: **O(n³)** (triple nested loop).
• Fastest for all tested sizes due to low overhead.
• Practical and simple, making it the most efficient choice for small and medium matrices.

Recursive Method

• Time Complexity: **O(n³)** (same as iterative, but implemented recursively).
• Slightly slower than iterative because of **function call overhead**.
• Useful for understanding recursion, but not efficient in practice.

Strassen's Algorithm

• Time Complexity: **O(n^log$_2$7) ≈ O(n^2.81)**, which is theoretically better than O(n³).• However, in practice, it is **slower for small and medium matrix sizes** due to additional addition/subtraction operations and higher memory usage.

• It only starts becoming beneficial for **very large matrices** (much larger than 1024 × 1024).

Overall Observation

• Iterative approach is best for real-world practical use cases at small to medium scale.

• Recursive approach is mainly academic.

• Strassen shows theoretical improvement but only outperforms classical methods for extremely large matrices.