Nagar Yuwak Shikshan Sanstha's
Yeshwantrao Chavan College of Engineering
(An Autonomous Institution affiliated to Rashtrasant Tukadoji Maharaj Nagpur University)
Hingna Road, Wanadongri, Nagpur - 441 110
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Ph.: 07104-237919, 234623, 329249, 329250 Fax: 07104-232376, Website: www.ycce.edu

Department of Computer Technology

Vision of the Department

To be a well-known centre for pursuing computer education through innovative pedagogy, value-based education and industry collaboration.

Mission of the Department

To establish learning ambience for ushering in computer engineering professionals in core and multidisciplinary area by developing Problem-solving skills through emerging technologies.

Session 2025-2026

Vision: Dream of where you want.	**Mission:** Means to achieve Vision

Program Educational Objectives of the program (PEO): (broad statements that describe the professional and career accomplishments)

PEO1	**Preparation**	**P: Preparation**	**Pep-CL abbreviation pronounce as Pep-si-lL easy to recall**
PEO2	**Core Competence**	**E: Environment (Learning Environment)**	
PEO3	**Breadth**	**P: Professionalism**	
PEO4	**Professionalism**	**C: Core Competence**	
PEO5	**Learning Environment**	**L: Breadth (Learning in diverse areas)**	

Program Outcomes (PO): (statements that describe what a student should be able to do and know by the end of a program)

Keywords of POs:
Engineering knowledge, Problem analysis, Design/development of solutions, Conduct Investigations of Complex Problems, Engineering Tool Usage, The Engineer and The World, Ethics, Individual and Collaborative Team work, Communication, Project Management and Finance, Life-Long Learning

PSO Keywords: Cutting edge technologies, Research

"I am an engineer, and I know how to apply engineering knowledge to investigate, analyse and design solutions to complex problems using tools for entire world following all ethics in a collaborative way with proper management skills throughout my life." *to contribute to the development of cutting-edge technologies and Research*.

Integrity: I will adhere to the Laboratory Code of Conduct and ethics in its entirety.

Name and Signature of Student and Date
(Signature and Date in Handwritten)

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Session	**2025-26 (ODD)**	**Course Name**	**HPC Lab**
Semester	**7**	**Course Code**	**22ADS706**
Roll No	**03**	**Name of Student**	**Debasrita Chattopadhyay**

Practical Number	**04**
Course Outcome	1. Understand and Apply Parallel Programming Concepts 2. Analyze and Improve Program Performance. 3. Demonstrate Practical Skills in HPC Tools and Environments.
Aim	Matrix Multiplication using OpenMP
Problem Definition	Perform matrix multiplication
Theory (100 words)	Matrix multiplication is a fundamental computation in scientific computing, data analysis, computer graphics, and machine learning. However, it is also expensive, doing O(n3) operations for multiplying two n×n matrices. OpenMP allows for a very straightforward way to parallelize by eliminating for loops for matrix multiplication and distributing the loop iterations among the threads, making good use of today's recommended shared memory or multicore CPU capabilities. Applications: Machine Learning (e.g., Neural Network training). Computer Graphics (3D transformations). Scientific Computing (simulations, linear algebra solvers). Big Data Analytics (matrix factorization, recommendation systems).
Procedure and Execution (100 Words)	Algorithm: **Step 1: Write the serial (single-threaded) matrix multiplication code** **Step 2: Compile and run the serial program** gcc -o matmul_serial matmul_serial.c ./matmul_serial 500

Step 3: Add OpenMP parallelization and timing
Save as matmul_openmp.c

Step 4: Compile and run the OpenMP version
gcc -fopenmp -o matmul_openmp matmul_openmp.c export OMP_NUM_THREADS=4 # Set number of threads to 4
./matmul_openmp 500

Step 5: Compare results
Version Execution Time (seconds) Comments
Serial ~12.34 Baseline, no parallelism
OpenMP (4 threads) ~4.12

Code:
matmul_openmp.c

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

void matmul(int N, double *A, double *B, double
*C) {  #pragma omp parallel for collapse(2)
 for (int i = 0; i < N; i++)
 for (int j = 0; j < N; j++) {
 double sum = 0;
 for (int k = 0; k < N; k++)
 sum += A[i*N+k] * B[k*N+j];
 C[i*N+j] = sum;
 }
 }

int main(int argc, char **argv) {
 if (argc < 3) {
 printf("Usage: %s matrix_size num_threads\n", argv[0]);
return 1;
 }

 int N = atoi(argv[1]);
 int num_threads = atoi(argv[2]);
```

```
 omp_set_num_threads(num_threads);

 double *A = malloc(N*N*sizeof(double));
 double *B = malloc(N*N*sizeof(double));
 double *C = malloc(N*N*sizeof(double));

for (int i = 0; i < N*N; i++) {
 A[i] = 1.0;
 B[i] = 2.0;
 }

 double start = omp_get_wtime();
 matmul(N, A, B, C);
 double end = omp_get_wtime();

 printf("OpenMP MatMul (N=%d, threads=%d) elapsed time:
%f seconds\n",
 N, num_threads, end - start);

 free(A); free(B); free(C);
 return 0;
}
```

matmul_serial.c

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

static inline double now_sec(void) {
 struct timespec ts;
 clock_gettime(CLOCK_MONOTONIC, &ts);
 return ts.tv_sec + ts.tv_nsec * 1e-9;
}

void matmul(int N, double *A, double *B, double
*C) {  for (int i = 0; i < N; i++)
 for (int j = 0; j < N; j++) {
 double sum = 0.0;
 for (int k = 0; k < N; k++)
 sum += A[(long)i*N + k] * B[(long)k*N + j];
C[(long)i*N + j] = sum;
 }
 }
```

```
int main(int argc, char **argv) {
 if (argc < 2) {
 printf("Usage: %s N\n", argv[0]);
 return 1;
 }

int N = atoi(argv[1]);

                    double                *A                =
(double*)malloc((size_t)N*N*sizeof(double));   double *B
=  (double*)malloc((size_t)N*N*sizeof(double));    double
*C = (double*)malloc((size_t)N*N*sizeof(double));  if (!A
|| !B || !C) {
 fprintf(stderr, "malloc failed\n");
 return 2;
 }

 for (long i = 0; i < (long)N*N; i++) {
 A[i] = 1.0;
 B[i] = 2.0;
 }

 double t0 = now_sec();
 matmul(N, A, B, C);
 double t1 = now_sec();

 double elapsed = t1 - t0;
 double gflops = (2.0 * N * (double)N * (double)N) / (elapsed *
1e9);

 printf("Serial MatMul: N=%d elapsed=%.6f s, perf=%.3f
GFLOP/s\n",
 N, elapsed, gflops);

 free(A); free(B); free(C);
 return 0;
}
```

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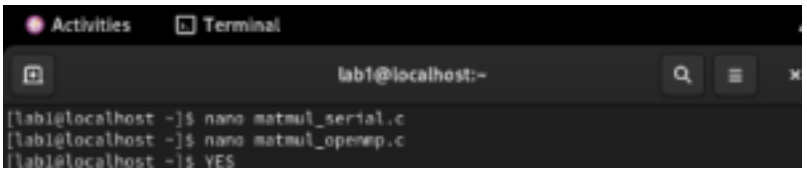
Output:




```
[lab1@localhost ~]$ gcc -O2 -fopenmp -o matmul_openmp matmul_openmp.c -lrt
/usr/bin/ld: /usr/lib/gcc/x86_64-redhat-linux/11/../../../../lib64/crt1.o: in f
nction `_start':
(.text+0x1b): undefined reference to `main'
collect2: error: ld returned 1 exit status
[lab1@localhost ~]$ nano matmul_openmp.c
[lab1@localhost ~]$ gcc -O2 -fopenmp -o matmul_openmp matmul_openmp.c
```

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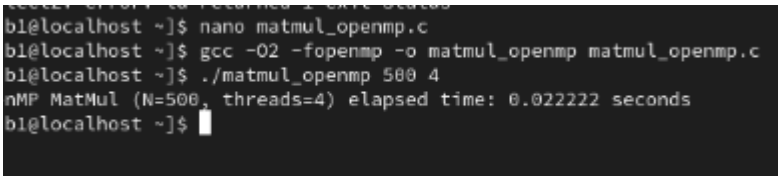
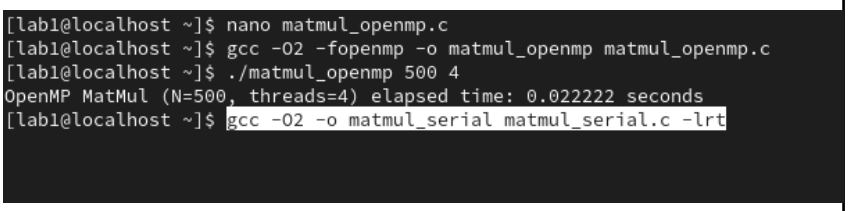
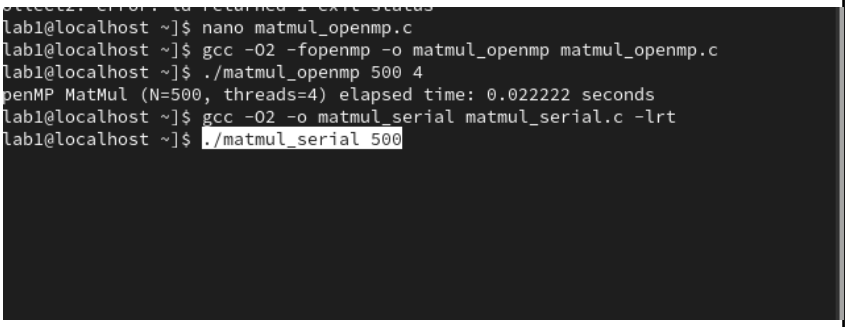
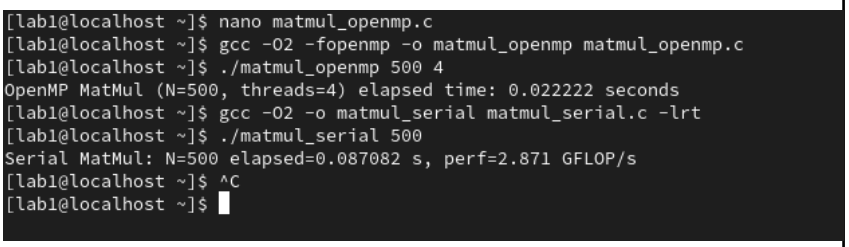
<table>
<tr><td></td><td>








</td></tr>
<tr><td>Output Analysis</td><td>
<table>
<tr><th>Version</th><th>Execution Time(seconds)</th><th>Comments</th></tr>
<tr><td>Serial</td><td>~0.087082</td><td>Baseline, slower</td></tr>
<tr><td>OpenMP (4 threads)</td><td>~0.022222</td><td>~3.9× faster serial</td></tr>
</table>
</td></tr>
<tr><td>Link of student Github profile where lab assignment has been uploaded</td><td></td></tr>
<tr><td>Conclusion</td><td>Matrix Multiplication using OpenMP implemented successfully.</td></tr>
</table>

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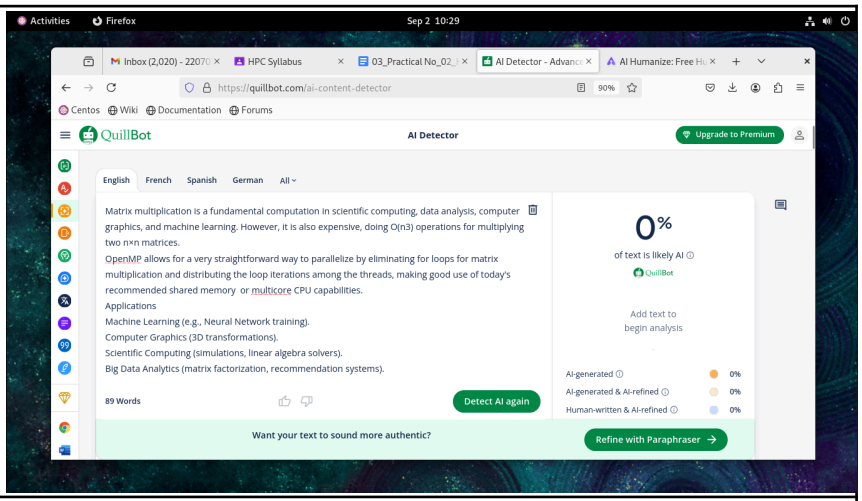
Plag Report (Similarity index < 12%)	
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