



## 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

<b>Vision:</b> Dream of where you want.	<b>Mission:</b> Means to achieve Vision
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**Program Educational Objectives of the program (PEO):** (broad statements that describe the professional and career accomplishments)

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

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

<b>Practical Number</b>	<b>02</b>
<b>Course Outcome</b>	1. Understand and Apply Parallel Programming Concepts 2. Analyze and Improve Program Performance. 3. Demonstrate Practical Skills in HPC Tools and Environments.
<b>Aim</b>	Measuring Program Performance
<b>Problem Definition</b>	Measuring Performance of Matrix Multiplication
<b>Theory</b> (100 words)	<p>Program performance measurement means evaluating how efficiently a program executes in terms of runtime, CPU utilization, memory usage, and scalability in a High-Performance Computing (HPC) environment.</p> <p>Performance Metrics to Check</p> <ol style="list-style-type: none"><li>1. Execution Time – total time taken.</li><li>2. CPU Utilization – efficiency of CPU use.</li><li>3. Memory Usage – peak memory consumption.</li><li>4. Scalability – speedup with more cores/nodes</li></ol> <p>Program performance in Linux HPC can be measured using Linux commands (time, top), built-in timing functions (omp_get_wtime, MPI_Wtime), scheduler reports (seff, sacct), and profiling tools (gprof, perf).</p> <p>Methods to Measure Performance:</p> <p>Using Linux Commands</p> <p>Built-in Timing Functions in Code</p> <p>HPC Scheduler Tools (e.g., SLURM, PBS)</p>
<b>Procedure and Execution</b> (100 Words)	<p>Algorithm:</p> <p><b>Step 1: Write the serial (single-threaded) matrix multiplication code</b></p> <p><b>Step 2: Compile and run the serial program</b></p> <pre>gcc -o matmul_serial matmul_serial.c ./matmul_serial 500</pre>

**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.***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 &lt;stdio.h&gt;

#include &lt;stdlib.h&gt;

#include &lt;omp.h&gt;

void matmul(int N, double \*A, double \*B, double \*C) {

#pragma omp parallel for collapse(2)

for (int i = 0; i &lt; N; i++)

for (int j = 0; j &lt; N; j++) {

double sum = 0;

for (int k = 0; k &lt; N; k++)

sum += A[i\*N+k] \* B[k\*N+j];

C[i\*N+j] = sum;

}

}

int main(int argc, char \*\*argv) {

if (argc &lt; 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));



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```
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;
    }
}
```



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```
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;
}
```

Output:

```
lab1@localhost:~
[lab1@localhost ~]$ nano matmul_serial.c
[lab1@localhost ~]$
```



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```
lab1@localhost:~ -- nano matmul_openmp.c
GNU nano 5.6.1 matmul_openmp.c Modified
Save modified buffer?
Y Yes
N No Cancel
```

```
lab1@localhost:~
[lab1@localhost ~]$ nano matmul_serial.c
[lab1@localhost ~]$ nano matmul_openmp.c
[lab1@localhost ~]$ YFS
```

```
[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 function '_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
```

```
bl@localhost ~]$ nano matmul_openmp.c
bl@localhost ~]$ gcc -O2 -fopenmp -o matmul_openmp matmul_openmp.c
bl@localhost ~]$ ./matmul_openmp 500 4
nMP MatMul (N=500, threads=4) elapsed time: 0.022222 seconds
bl@localhost ~]$
```



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	<pre>[lab1@localhost ~]\$ nano matmul_openmp.c [lab1@localhost ~]\$ gcc -O2 -fopenmp -o matmul_openmp matmul_openmp.c [lab1@localhost ~]\$ ./matmul_openmp 500 4 OpenMP MatMul (N=500, threads=4) elapsed time: 0.022222 seconds [lab1@localhost ~]\$ gcc -O2 -o matmul_serial matmul_serial.c -lrt [lab1@localhost ~]\$</pre> <pre>gcc: error: ld returned 1 exit status [lab1@localhost ~]\$ nano matmul_openmp.c [lab1@localhost ~]\$ gcc -O2 -fopenmp -o matmul_openmp matmul_openmp.c [lab1@localhost ~]\$ ./matmul_openmp 500 4 OpenMP MatMul (N=500, threads=4) elapsed time: 0.022222 seconds [lab1@localhost ~]\$ gcc -O2 -o matmul_serial matmul_serial.c -lrt [lab1@localhost ~]\$ ./matmul_serial 500</pre> <pre>[lab1@localhost ~]\$ nano matmul_openmp.c [lab1@localhost ~]\$ gcc -O2 -fopenmp -o matmul_openmp matmul_openmp.c [lab1@localhost ~]\$ ./matmul_openmp 500 4 OpenMP MatMul (N=500, threads=4) elapsed time: 0.022222 seconds [lab1@localhost ~]\$ gcc -O2 -o matmul_serial matmul_serial.c -lrt [lab1@localhost ~]\$ ./matmul_serial 500 Serial MatMul: N=500 elapsed=0.087082 s, perf=2.871 GFLOP/s [lab1@localhost ~]\$ ^C [lab1@localhost ~]\$</pre>									
Output Analysis	<table><tr><th>Version</th><th>Execution Time (seconds)</th><th>Comments</th></tr><tr><td>Serial</td><td>~0.087082</td><td>Baseline, no parallelism, slower execution</td></tr><tr><td>OpenMP (4 threads)</td><td>~0.022222</td><td>Shared-memory parallelism, ~3.9× faster than serial</td></tr></table>	Version	Execution Time (seconds)	Comments	Serial	~0.087082	Baseline, no parallelism, slower execution	OpenMP (4 threads)	~0.022222	Shared-memory parallelism, ~3.9× faster than serial
Version	Execution Time (seconds)	Comments								
Serial	~0.087082	Baseline, no parallelism, slower execution								
OpenMP (4 threads)	~0.022222	Shared-memory parallelism, ~3.9× faster than serial								
Link of student Github profile where lab assignment has been uploaded										
Conclusion	Measuring Program Performance implemented successfully.									
Plag Report (Similarity index < 12%)										

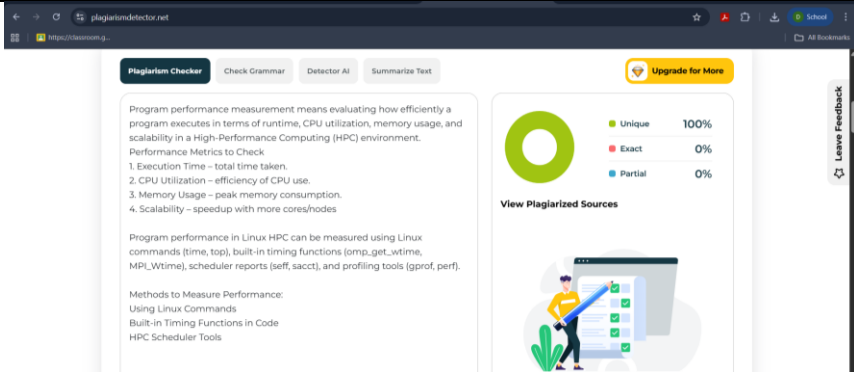
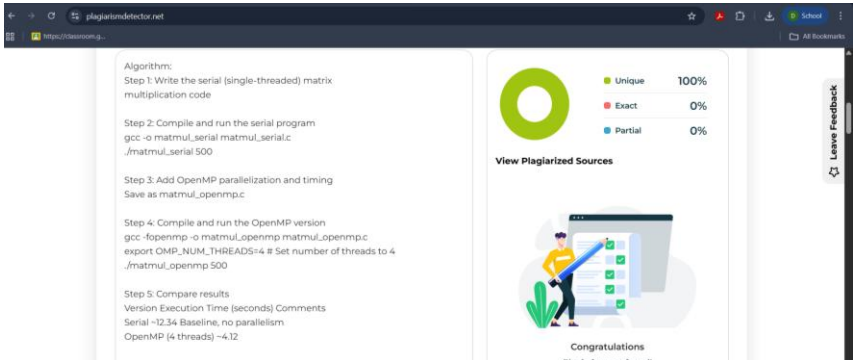


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Date	26 / 8 / 25