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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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: To help businesses uncover crucial insights	**Mission:** To be a good data scientist

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): 1. Understand and Apply Parallel Programming Concepts

2. Analyse and Improve Program Performance.

3. Demonstrate Practical Skills in HPC Tools and Environments.

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
soham pimpalgaonkar – 28/10/2025

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Session	**2025-26 (ODD)**	**Course Name**	**HPC Lab**
Semester	**7**	**Course Code**	22ADS706
Roll No	62	**Name of Student**	Soham pimpalgaonkar

Practical Number	7
Course Outcome	1. Understand and Apply Parallel Programming Concepts 2. Analyse and Improve Program Performance
Aim	Hybrid Programming with MPI + OpenMP Practical
Problem Definition	Hybrid Programming with MPI + OpenMP Practical

Theory (100 words)	**Requirements**
	• **Software:**
	  • Linux OS (Ubuntu/RedHat recommended)
	  • MPI library (OpenMPI / MPICH)
	  • GCC compiler with OpenMP support
	• **Hardware:**
	  • Multi-core processor
	  • Optional: Cluster with multiple nodes for full MPI execution
	
	1. MPI (Message Passing Interface)
	  • Used for communication between processes in a distributed memory system.
	  • Each process has its own address space.
	2. OpenMP (Open Multi-Processing)
	  • Used for parallelism within a shared memory node.
	  • Allows multi-threading using #pragma omp parallel.
	3. Hybrid Programming
	  • Combines MPI across nodes and OpenMP within nodes.
	  • Reduces communication overhead and improves parallel efficiency.
	
	Algorithm
	1. Initialize MPI and get rank and size.
	2. Distribute rows of the matrix A among MPI processes.

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	3. Each process computes its local result using OpenMP threads. 4. MPI_Reduce is used to gather results to the master process. 5. Master process prints the final result. **Steps for execution** **Step 1** - Compile: mpicc -fopenmp hybrid_mpi_openmp.c -o hybrid_mpi_openmp **Step 2** - Execute (using 2 MPI processes, adjust threads with OMP_NUM_THREADS): export OMP_NUM_THREADS=4 # Set number of OpenMP threads per process mpirun -np 2 ./hybrid_mpi_openmp

Code:	`#include <stdio.h>`
	`#include <stdlib.h>`
	`#include <mpi.h>`
	`#include <omp.h>`
	
	`#define N 8  // Size of matrix and vector`
	
	`int main(int argc, char* argv[]) {`
	`  int rank, size;`
	`  MPI_Init(&argc, &argv);`
	`  MPI_Comm_rank(MPI_COMM_WORLD, &rank);`
	`  MPI_Comm_size(MPI_COMM_WORLD, &size);`
	
	`  int rows_per_proc = N / size;`
	`  double A[rows_per_proc][N];`
	`  double x[N];`
	`  double y_local[rows_per_proc];`
	`  double y[N];`
	
	`  // Initialize vector x and matrix A`
	`  if(rank == 0) {`
	`  for(int i = 0; i < N; i++)`
	`  x[i] = i + 1;  // Example vector: 1,2,3...`
	`  }`
	
	`  MPI_Bcast(x, N, MPI_DOUBLE, 0, MPI_COMM_WORLD); // Broadcast vector to all processes`
	
	`  // Initialize local part of matrix A`
	`  for(int i = 0; i < rows_per_proc; i++) {`

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```
        for(int j = 0; j < N; j++) {
            A[i][j] = (rank * rows_per_proc + i + 1) * (j
+ 1);
        }
    }

    // Parallel computation using OpenMP
    #pragma omp parallel for
    for(int i = 0; i < rows_per_proc; i++) {
        y_local[i] = 0.0;
        for(int j = 0; j < N; j++) {
            y_local[i] += A[i][j] * x[j];
        }
    }

    // Gather results to root process
    MPI_Gather(y_local, rows_per_proc, MPI_DOUBLE, y,
rows_per_proc, MPI_DOUBLE, 0, MPI_COMM_WORLD);

    // Print result in master process
    if(rank == 0) {
        printf("Result vector y:\n");
        for(int i = 0; i < N; i++) {
            printf("%lf ", y[i]);
        }
        printf("\n");
    }

    MPI_Finalize();
    return 0;
}
```

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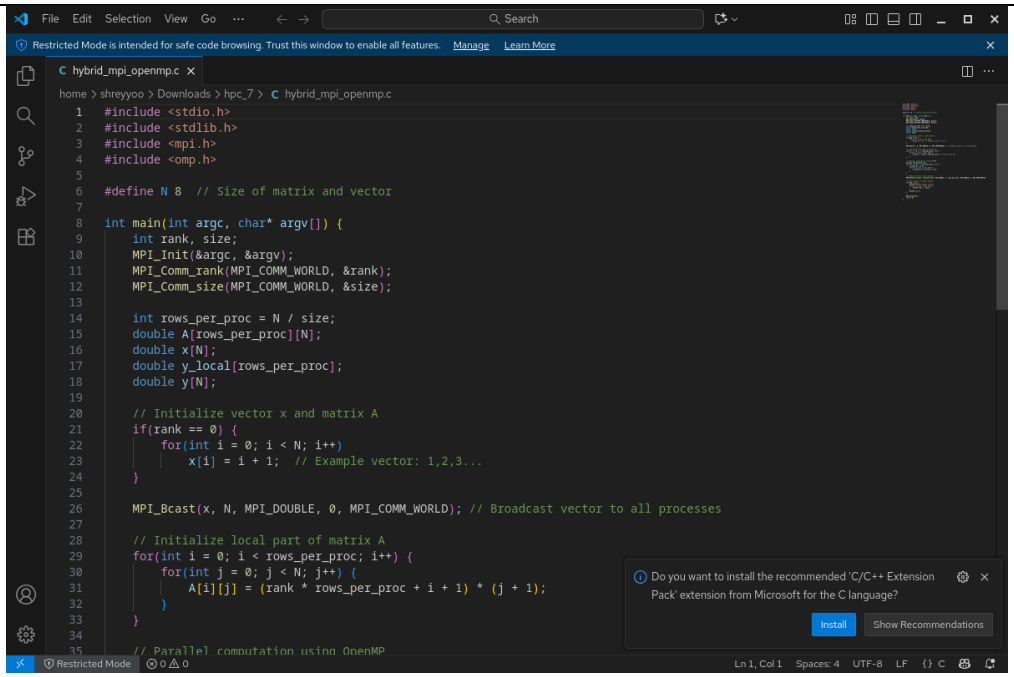
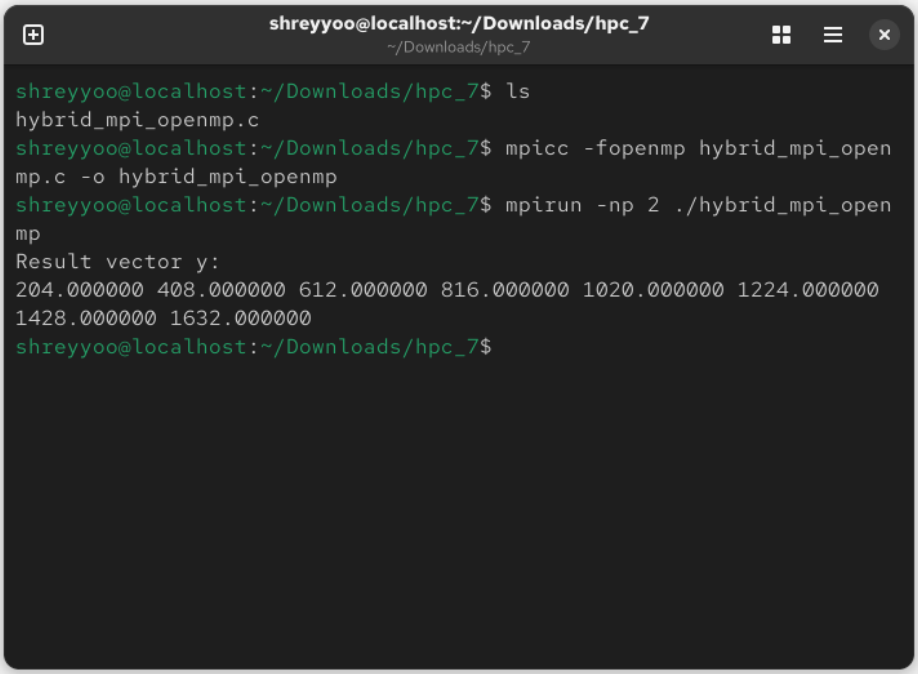
Output





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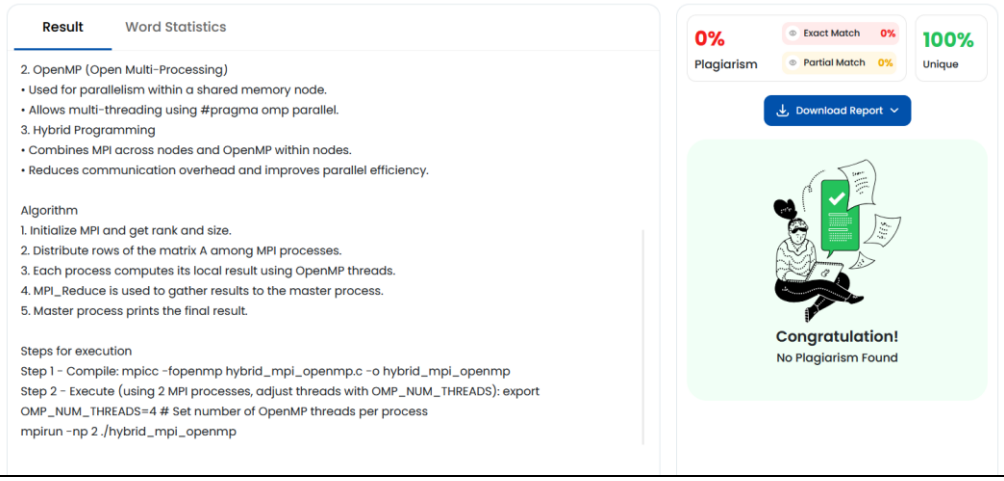
Output Analysis	The program executes successfully and gives us the resultant vector y as an output.
Link of student Github profile where lab assignment has been uploaded	**https://github.com/Sohampimpalgaonkar/HPC**
Conclusion	The experiment successfully compiled and ran a hybrid MPI/OpenMP parallel program using 2 MPI processes. The program executed correctly, as confirmed by the output of the 8-element result vector y demonstrating that the system and the parallel code are properly configured for hybrid high-performance computing.
Plag Report (Similarity index < 12%)	
Date	28/10/2025