Course: High Performance Computing Lab

Practical No 1

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Title: Introduction to OpenMP

**Problem Statement 1** – Demonstrate Installation and Running of OpenMP code in C
Recommended Linux based System:
Following steps are for windows:
OpenMP – Open Multi-Processing is an API that supports multi-platform shared-memory multiprocessing programming in C, C++ and Fortran on multiple OS. OpenMP uses a portable, scalable model that gives programmers a simple and flexible interface for developing parallel applications for platforms ranging from the standard desktop computer to the supercomputer.

To set up OpenMP,
We need to first install C, C++ compiler if not already done. This is possible through the MinGW Installer.
Reference: Article on GCC and G++ installer (Link)
Note: Also install mingw32-pthreads-w32 package.

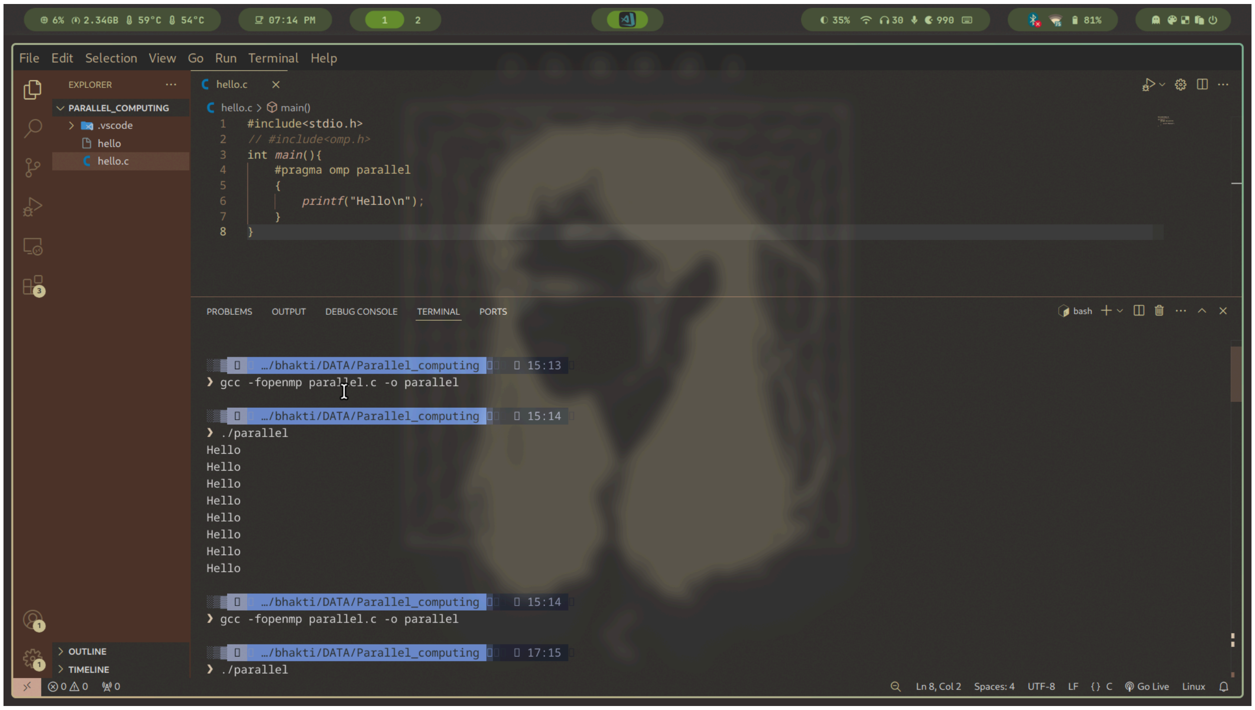
Then, to run a program in OpenMP, we have to pass a flag -fopenmp.
Example:
To run a basic Hello World,

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


int main(void)
{
   #pragma omp parallel
   printf("Hello, world.\n");
   return 0;
}
```

```
gcc -fopenmp test.c -o hello
.\hello.exe
```

Code/ Output snapshot:




Analysis:

**Step-by-step Explanation:**

1. **#include <stdio.h>**
    - Includes the standard input/output library so we can use printf().
2. **#include <omp.h>**
    - Includes the OpenMP library, which allows you to write parallel programs using simple #pragma commands.
3. **#pragma omp parallel**
    - This is an OpenMP *directive*.

   - It tells the compiler:
     "Run the next block of code **in parallel**, using multiple threads."

4. **printf("Hello, world.\n");**

   - Each thread **prints** this line.

5. **So what happens?**

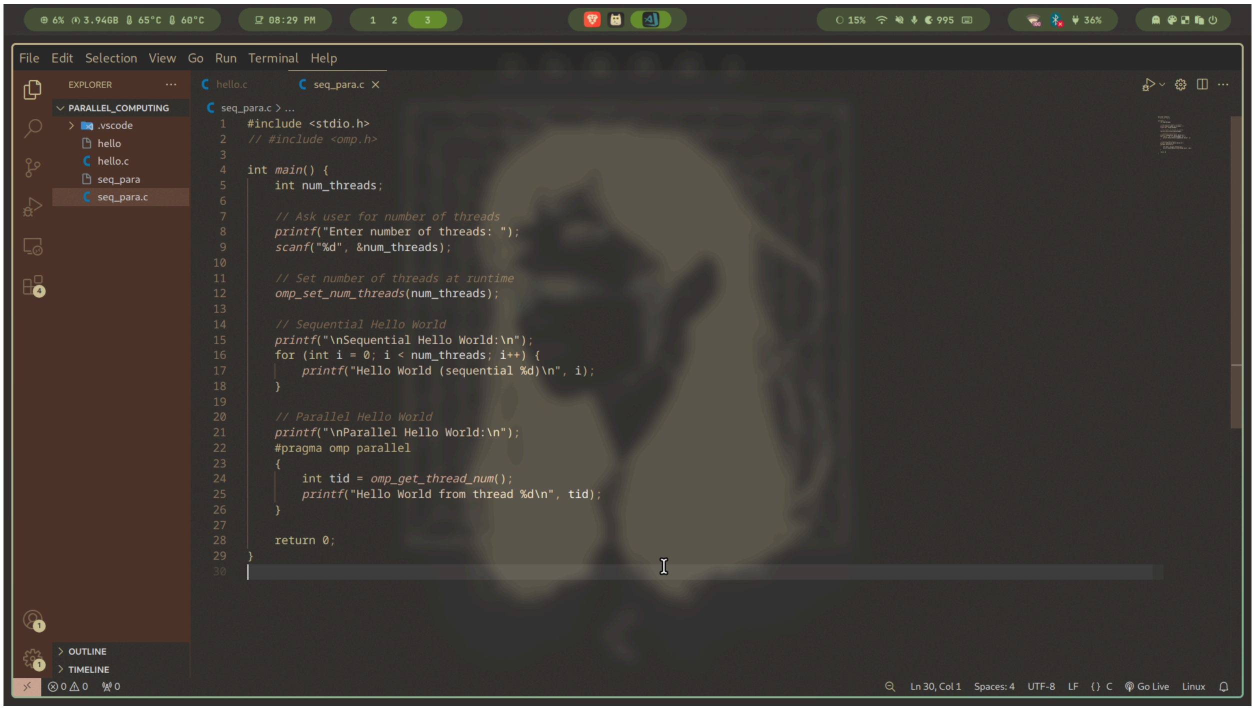
   - If your system runs with 4 threads, you will see the line **printed 4 times** (one from each thread).

   - The order of printing may look random (because threads run independently).

GitHub Link: https://github.com/bhaktimore18/hpc_lab

**Problem Statement 2** – Print 'Hello, World' in Sequential and Parallel in OpenMP
We first ask the user for number of threads – OpenMP allows to set the threads at runtime. Then, we print the Hello, World in sequential – number of times of threads count and then run the code in parallel in each thread.

Code Snapshots:




Output snapshots:


Analysis:

**What this program does:**

1. **It asks the user** how many threads they want to use.
2. It tells OpenMP to use that many threads when running parallel code.
3. Then it prints "Hello World" messages in two ways:
   - First, **sequentially** (one by one, using only the main thread).
   - Then, **in parallel** (many threads printing at the same time).

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**Explanation of Each Step:**

- The program starts by asking for a number, for example 4.
- It stores this number and tells OpenMP: "Use 4 threads."
- It then prints "Hello World (sequential 0)", "Hello World (sequential 1)", and so on up to 3 — this part is **not parallel**, so the order is always correct.
- Next, it enters a **parallel block**. OpenMP starts 4 threads.
- Each thread runs the print statement and says "Hello World from thread X", where X is the thread's ID.
- Since this runs in **parallel**, the order may change every time you run it.

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**Behind the scenes:**

- omp_set_num_threads() sets how many threads OpenMP will use.
- omp_get_thread_num() gets the ID of each thread (like 0, 1, 2, etc).
- The parallel block tells all threads to run the same code.

**Problem statement 3**: Calculate theoretical FLOPS of your system on which you are running the above codes. Elaborate the parameters and show calculation

**Theoretical FLOPS = Number of cores × Clock speed × FLOPs per cycle**
Assuming:

- Number of cores = 4
- Clock speed = 3.0 GHz = $3 \times 10^9$ Hz
- FLOPs per cycle = 8

**FLOPS =** $\mathbf{4 \times 3 \times 10^9 \times 8 = 96 \times 10^9}$ **= 96 GFLOPS**

The theoretical peak performance of the system is **96 GFLOPS** (96 billion floating-point operations per second).

**Theoretical FLOPS** means how fast your CPU *can* do decimal (floating-point) math per second.

In this case:

- The CPU has **4 cores** (4 brains working together)
- Each core runs at **3.0 GHz** (3 billion steps per second)
- Each core can do **8 floating-point operations in one step**

So, in total:

**4 × 3 billion × 8 = 96 billion operations per second**,
which is **96 GFLOPS**.