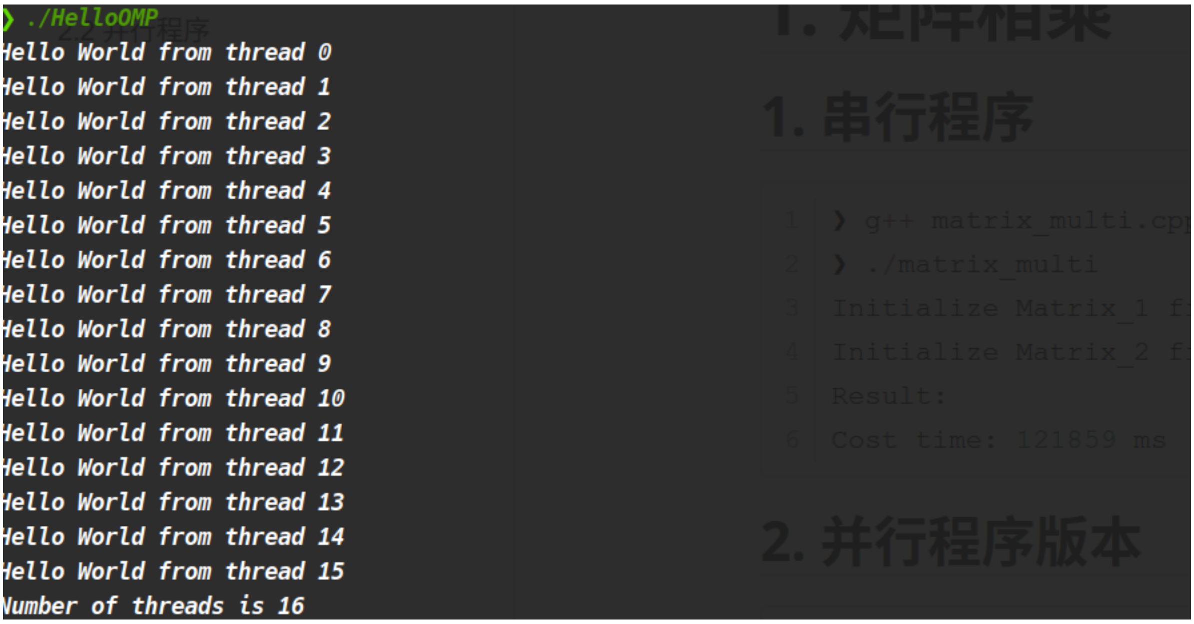
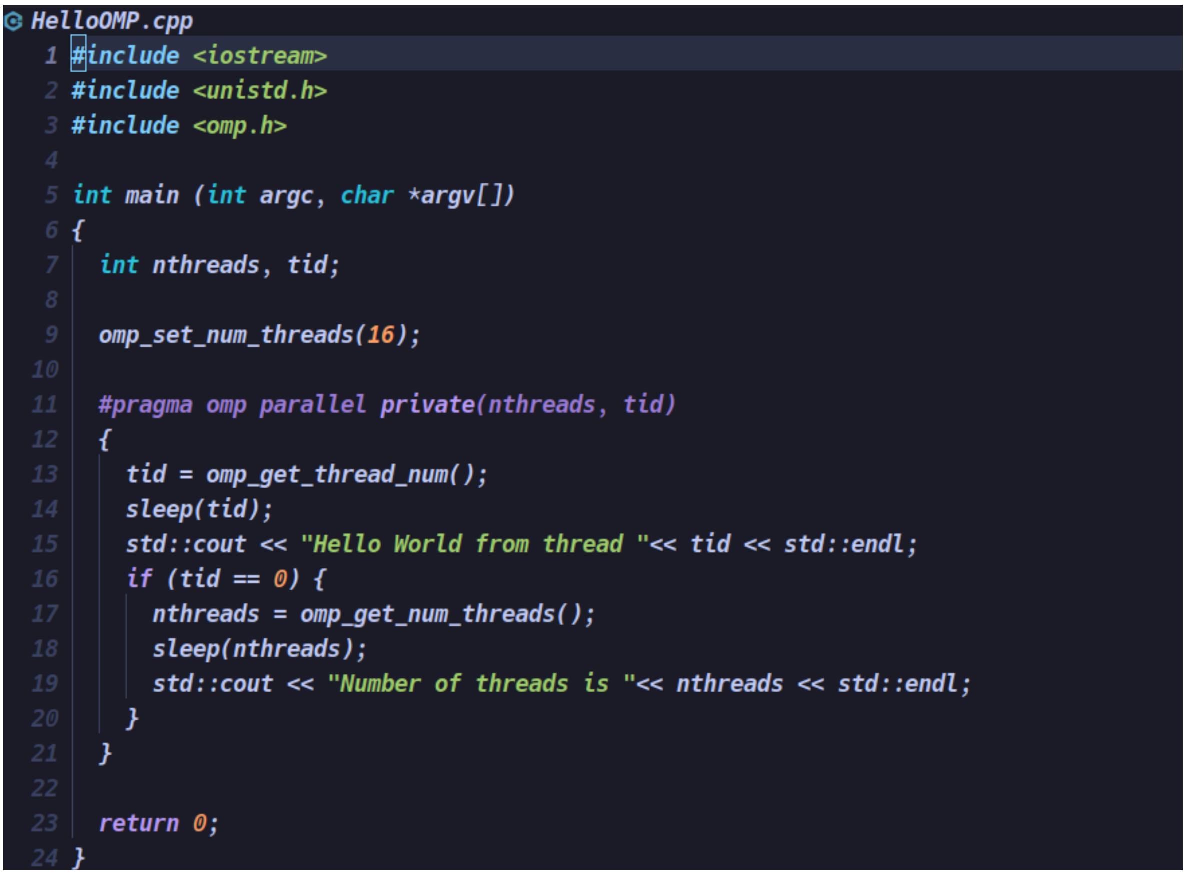
# 1. OpenMP程序的编译和运行

## 1.1 执行结果：



```
❯ ./HelloOMP
Hello World from thread 0
Hello World from thread 1
Hello World from thread 2
Hello World from thread 3
Hello World from thread 4
Hello World from thread 5
Hello World from thread 6
Hello World from thread 7
Hello World from thread 8
Hello World from thread 9
Hello World from thread 10
Hello World from thread 11
Hello World from thread 12
Hello World from thread 13
Hello World from thread 14
Hello World from thread 15
Number of threads is 16
```

## 1.2 相关代码：



HelloOMP.cpp

```cpp
#include <iostream>
#include <unistd.h>
#include <omp.h>

int main (int argc, char *argv[])
{
  int nthreads, tid;

  omp_set_num_threads(16);

  #pragma omp parallel private(nthreads, tid)
  {
    tid = omp_get_thread_num();
    sleep(tid);
    std::cout << "Hello World from thread "<< tid << std::endl;
    if (tid == 0) {
      nthreads = omp_get_num_threads();
      sleep(nthreads);
      std::cout << "Number of threads is "<< nthreads << std::endl;
    }
  }

  return 0;
}
```

# 2. 矩阵乘法的OpenMP实现与性能分析

## 2.1 串行程序执行结果

```
❯ g++ matrix_multi.cpp -o matrix_multi
❯ ./matrix_multi
Initialize Matrix_1 finished
Initialize Matrix_2 finished
Result:
Cost time: 121859 ms
```

## 2.2 并行程序版本执行结果

```
#pragma omp parallel for shared(a, b, result) private(j, k) schedule(dynamic)
    // #pragma omp parallel for
    for (i = 0; i < max; i++) {
      for (j = 0; j < max; j++) {
        int temp = 0;
        for (k = 0; k < max; k++) {
          temp += a[i][k]* b[k][j];
        }
        result[i][j] = temp;
      }
    }
```

```
❯ lvim matrix_multi_parallel_v1.cpp
❯ g++ -fopenmp matrix_multi_parallel_v1.cpp -o parallel_v1
❯ ./parallel_v1
Initialize Matrix_1 finished
Initialize Matrix_2 finished
Result:
Cost time: 20700 ms
The Max of error is :0
Average Error is :0
```

我们经过计算可以得到加速比为5.89。

## 2.3 测试性能

### 2.3.1 线程数量一定，矩阵规模不一定

**线程数量一定为8；**

| 矩阵大小 | 200*200 | 1500*1500 | 2000*2000 | 2500*2500 |
|---|---|---|---|---|
| 运行时间（ms） | 36 | 8219 | 20698 | 43692 |

### 2.3.2 矩阵规模一定，线程数量不一定

**矩阵规模一定为2000*2000；**

| 线程数量 | 1 | 2 | 4 | 8 | 16 |
|---|---|---|---|---|---|
| 运行时间（ms） | 100610 | 50251 | 25862 | 20698 | 21643 |

# 3. 通过积分计算π

求出$\int_0^1 \frac{4}{1+x^2}\frac{\mathrm{d}}{\mathrm{d}x}$的值。

## 2.1 串行程序

```cpp
#include <iostream>
#include <chrono>

using namespace std;

static long num_step = 100000000;
double step;
int main (int argc, char *argv[])
{
  int i;
  double x, pi, sum = 0.0;

  step = 1.0/(double) num_step;


  chrono::milliseconds start_time = chrono::duration_cast<chrono::milliseconds>(chrono::system_clock::now().time_since_epoch());
  for (i = 0; i < num_step; ++i) {
    x = (i + 0.5) * step;
    // x = (i + 0.4) * step;
    sum = sum + 4.0/(1.0 + x * x);
  }
  chrono::milliseconds end_time = chrono::duration_cast<chrono::milliseconds>(chrono::system_clock::now().time_since_epoch());
  pi = step * sum;

  std::cout <<"The result: "<< pi << std::endl;
  cout << "cost time: " <<  chrono::milliseconds(end_time).count() - chrono::milliseconds(start_time).count() << "ms" << endl;

  return 0;
}
```

运行结果：

```
❯ g++ first.cpp -o first
❯ ./first
The result: 3.14159
cost time: 215ms
```

## 2.2 并行程序

```cpp
#include <iostream>
#include <chrono>
#include <omp.h>
```

```cpp
using namespace std;

static long num_step = 100000000;
double step;
#define NUM_THREADS 8
int main (int argc, char *argv[])
{

  double pi = 0.0;
  step = 1.0/(double) num_step;
  int number;


  chrono::milliseconds start_time = chrono::duration_cast<chrono::milliseconds>(chrono::system_clock::now().time_since_epoch());
  omp_set_num_threads(NUM_THREADS);
  #pragma omp parallel
  {
    int i, id, nthreads;
    double x, sum;
    id = omp_get_thread_num();
    nthreads = omp_get_num_threads();
    if (id == 0) {
      number = nthreads;
    }
    #pragma omp for
    for (i = 0; i < num_step; ++i) {
      x = (i + 0.5) * step;
      // x = (i + 0.4) * step;
      sum = sum + 4.0/(1.0 + x * x);
    }
    #pragma omp critical
    pi = step * sum;
  }
  chrono::milliseconds end_time = chrono::duration_cast<chrono::milliseconds>(chrono::system_clock::now().time_since_epoch());

  std::cout <<"The result: "<< pi << std::endl;
  cout << "cost time: " <<  chrono::milliseconds(end_time).count() - chrono::milliseconds(start_time).count() << "ms" << endl;

  return 0;
}

```

程序执行结果：

```
❯ ./PI_Parallel_v2
The result: 3.14159
cost time: 52ms
```

我们经过计算可以得到加速比为4.13.