Heterogeneous Computing using openMP lecture 1

F21DP Distributed and Parallel Technology

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Introduction to OpenMP

- What is OpenMP?
  - Open specification for Multi-Processing
  - "Standard" API for defining multi-threaded shared-memory programs
  - openmp.org – Talks, examples, forums, etc.

- High-level API
  - Preprocessor (compiler) directives (~ 80%)
  - Library Calls (~ 19%)
  - Environment Variables (~ 1%)

A Programmer's View of OpenMP

- OpenMP is a portable, threaded, shared-memory programming *specification* with "light" syntax
  - Exact behavior depends on OpenMP *implementation*!
  - Requires compiler support (C or Fortran)

- OpenMP will:
  - Allow a programmer to separate a program into *serial regions* and *parallel regions*
  - Hide stack management
  - Provide synchronisation constructs

- OpenMP will not:
  - Parallelize automatically
  - Guarantee speedup
  - Provide freedom from data races

Digging in

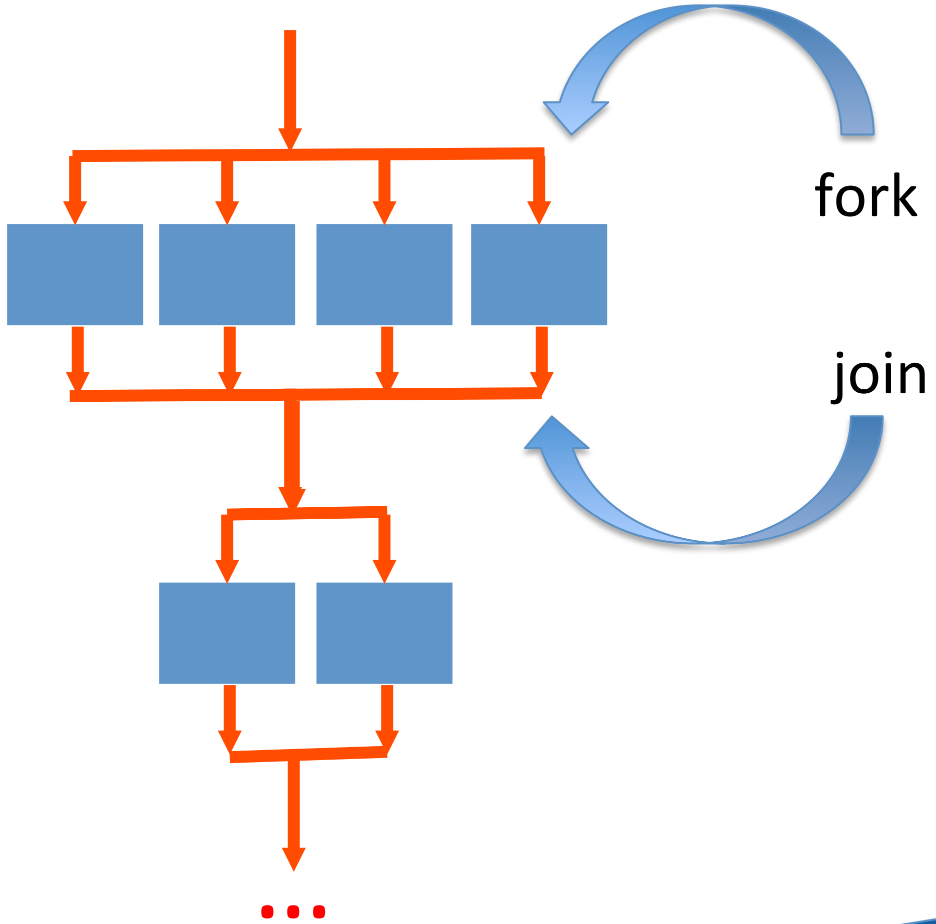
```
int main() {

  // Do this part in parallel

  printf( "Hello, World!\n" );

  return 0;
}
```

Motivation – OpenMP

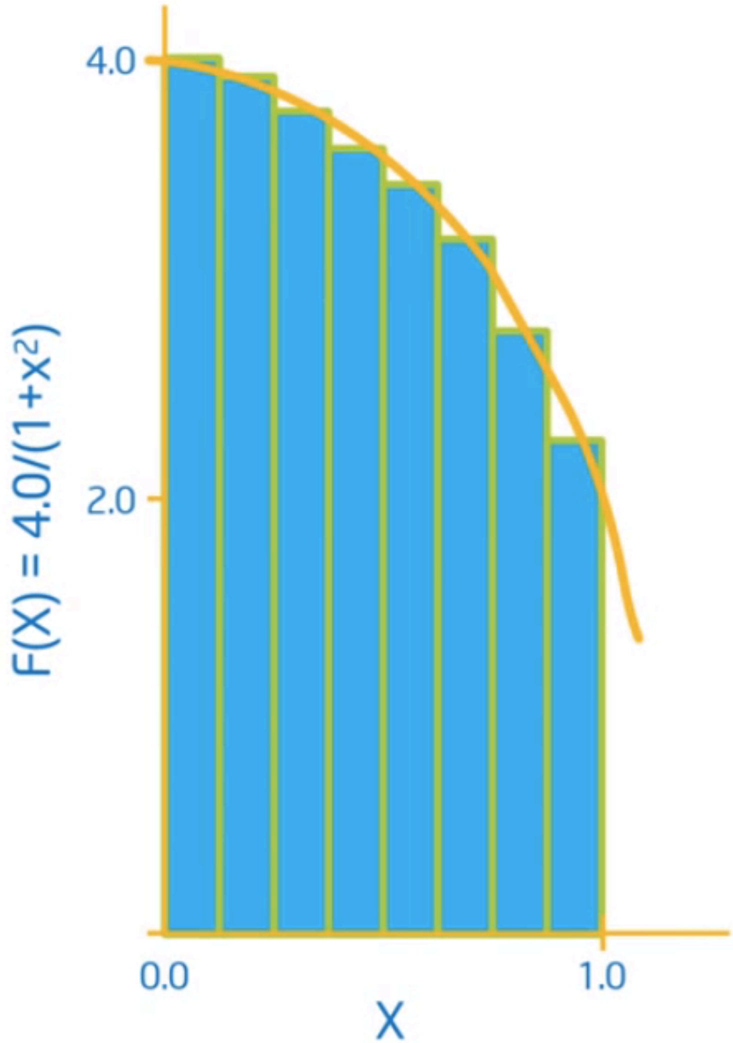
```
#include <omp.h>

int main() {

  omp_set_num_threads(16);

  // Do this part in parallel
  #pragma omp parallel
  {
    printf( "Hello, World!\n" );
  }

  return 0;
}
```

compile with *–fopenmp*   !!!!

Programming Model



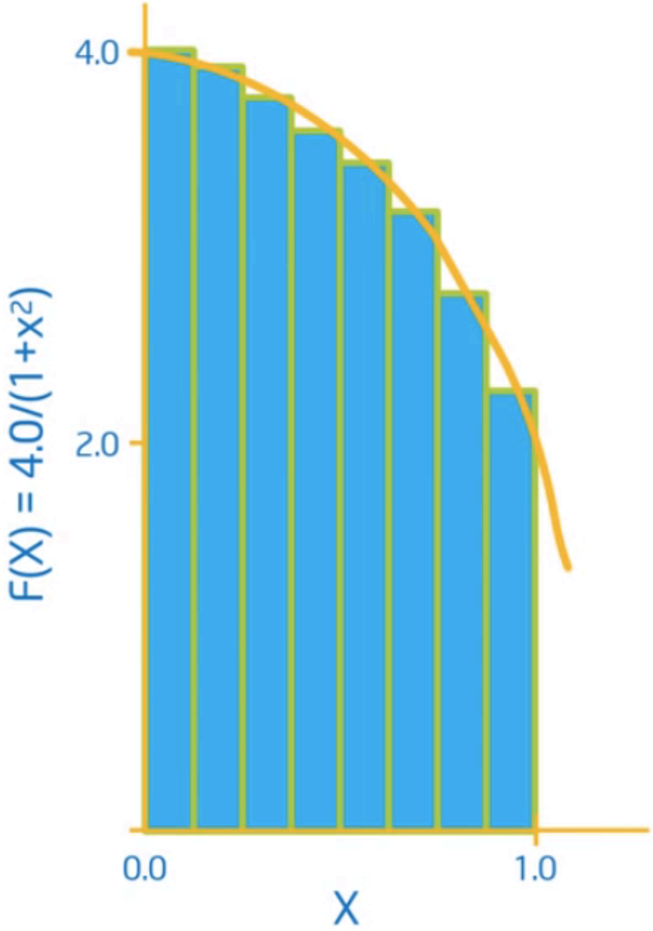
Computation of π



$$\int_0^1 \frac{4.0}{(1+X^2)}$$

C implementation

```c
int num_steps = 10000;
double step;

int main()
{
   int i; double x, pi, sum=0.0;

   step = 1.0/(double)num_steps;
   for( i=0; i<num_steps; i++) {
      x = (i+0.5) * step;
      sum += 4.0/(1.0+x*x);
   }
   pi = step * sum;
   ...
}
```



Exposing Concurrency

```
#include<omp.h>
int num_steps = 10000;
double step;

int main()
{
   int i; double x, pi, sum=0.0;
   step = 1.0/(double)num_steps;
   omp_set_num_threads( 10);
   #pragma_omp_parallel
   {
   for( i=0; i<num_steps; i++) {
      x = (i+0.5) * step;
      sum += 4.0/(1.0+x*x);
   }
   }

   pi = step * sum;
   ...
}
```

shared!!!

Exposing Concurrency

```
int main()
{
   int i; double x, pi, sum=0.0;
   step = 1.0/(double)num_steps;
   omp_set_num_threads( 10);
   #pragma_omp_parallel
   {
     int i, id; num_threads;
     double x;
     id = omp_get_thread_num();
     num_threads = omp_get_num_threads();

    for( i= id; i<num_steps; i=i+num_threads ) {
       x = (i+0.5) * step;
       sum += 4.0/(1.0+x*x);
    }
  }
```

race condition!!!

Elimination of the Race Condition

```
int main()
{
   int i; double x, pi, sum[10] =0.0; int num_t;
   step = 1.0/(double)num_steps;
    omp_set_num_threads( 10);
   #pragma_omp_parallel
   { int i, id, num_threads;
     double x;
     id = omp_get_thread_num();
     num_threads = omp_get_num_threads();
     if( id==0) num_t = num_threads;
     for( i= id    ; i<num_steps; i = i + num_threads  ) {
        x = (i+0.5) * step;
        sum [id]  += 4.0/(1.0+x*x);
     }
   }
   for(i=0; i<num_threads; i++)
      pi += sum[i] * step;
}
```

UGLY !!!

not in scope!!!

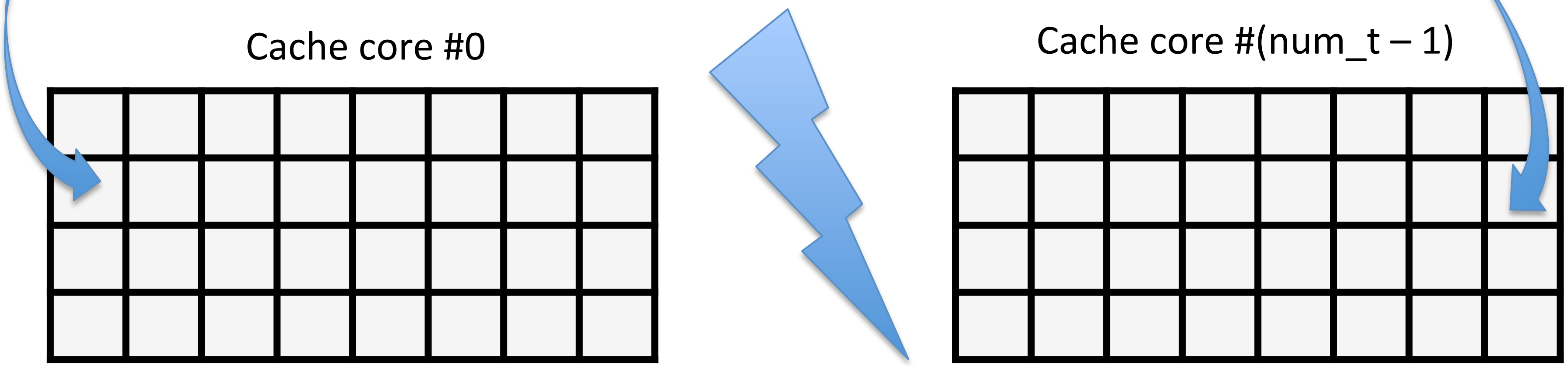
Adding Insult to Injury

```
int main()
{
   int i; double x, pi, sum [10] =0.0; int num_t;
   step = 1.0/(double)num_steps;
    omp_set_num_threads( 10);
   #pragma_omp_parallel
   { int i, id, num_threads;
     double x;
     id = omp_get_thread_num();
     num_threads = omp_get_num_threads();
     if( id==0) num_t = num_threads;
     for( i=  id    ; i<num_steps; i = i + num_threads  ) {
       x = (i+0.5) * step;
       sum [id]  += 4.0/(1.0+x*x);
     }
    }
    for(i=0; i< num_t; i++)
       pi += sum[i] * step;
}
```

slow !!!

False Sharing!

sum **[0]** += 4.0/(1.0+x*x); .... sum **[num_t - 1]** += 4.0/(1.0+x*x);



Cache invalidation on every single write!!!

Summary so far

- Introduction of concurrency is easy!
- Pitfalls:
  - scope of variables (global/local)
  - race conditions
  - false sharing

=> constructs introduced so far are too rudimentary!!