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Heterogeneous Computing using openMP lecture 2

F21DP Distributed and Parallel Technology

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Adding Insult to Injury

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```
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;
}
```

Synchronisation in openMP

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- **#pragma omp barrier**
  - synchronises across all threads
- **#pragma omp critical {}**
  - ensures mutual exclusion
- **#pragma omp atomic {}** 4.0
  - tries to use ***an*** atomic operation, i.e. only works for very simple operations. If not possible, it turns into omp critical

Using Critical Sections

```
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;
      #pragma omp critical
      {sum[id]  += 4.0/(1.0+x*x);}
     }
    }
    for(i=0; i< num_t; i++)
    pi = sum * step;
        pi += sum[i]* step;
}
```

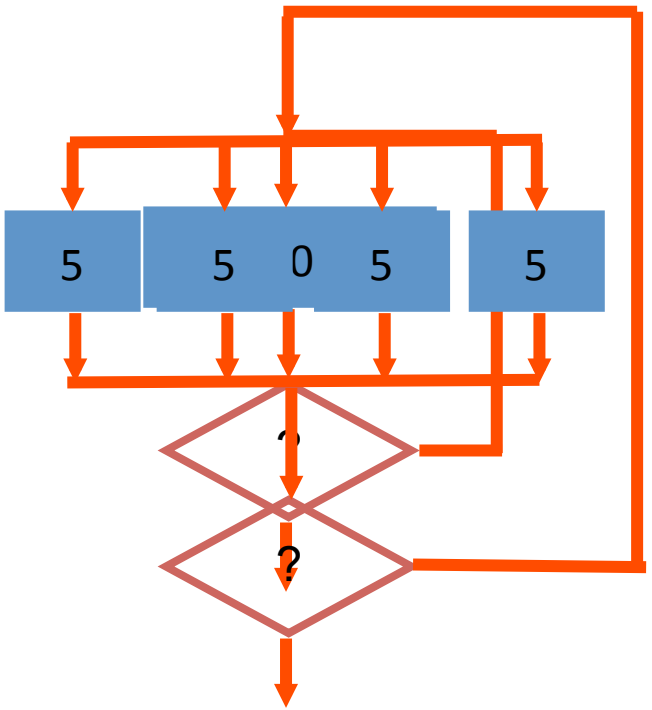
Going Atomic

```
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;
       x = 4.0/(1.0+x*x);
       #pragma omp atomic
       { sum += 4.0/(1.0+x*x);}
      }
   }
   pi = sum * step;
}
```

Concurrent Loops

- OpenMP provides a loop pattern!!
  - Requires: No data dependencies (reads/write or write/write pairs) between iterations!
- Preprocessor calculates loop bounds for each thread directly from *serial* source
- Scheduling no longer hand-coded




```
#pragma omp parallel
{ #pragma omp for
  for( i=0; i < 20; i++ )
  {
    printf("Hello World!");
  }
}
```

Loop Scheduling

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- schedule clause determines how loop iterations are divided among the thread team
  - **static([chunk])** divides iterations statically between threads
    - Each thread receives [chunk] iterations, rounding as necessary to account for all iterations
    - Default **[chunk]** is **ceil(# iterations / # threads)**
  - **dynamic([chunk])** allocates **[chunk]** iterations per thread, allocating an additional **[chunk]** iterations when a thread finishes
    - Forms a logical work queue, consisting of all loop iterations
    - Default **[chunk]** is 1
  - **guided([chunk])** allocates dynamically, but **[chunk]** is exponentially reduced with each allocation

Loop Scheduling II

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- schedule clause determines how loop iterations are divided among the thread team
  - **auto** leaves the choice to the compiler
  - **runtime** enables dynamic control through
    - Environment variable **OMP_SCHEDULE** *type*
    - Library function **omp_set_schedule**(*type*)

Using *OMP FOR*

```
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();
     #pragma omp for schedule static(1)
     num_threads = omp_get_num_threads();

     for(i=0; i<num_steps; i++){i = i + num_threads  ) {
       x = (i+0.5) * step;
       x = 4.0/(1.0+x*x);
      #pragma omp atomic
      { sum += x ; }
     }
   }
   pi = sum * step;
}
```

Reductions

- Typical pattern:

```
double vect[N];
double accu = neutral;

for( i=0; i<N; i++) {
   accu = accu op big_load(i);
}
```

- Examples: sum / product / mean / …

Reductions

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```
double vect[N];
double accu = neutral;

#pragma omp parallel for reduction( op: accu)

for( i=0; i<N; i++) {
   accu = accu op big_load(i);
}
```

Using ***Reduction***

```
int main()
{
   int i; double x, pi, sum =0.0;
   step = 1.0/(double)num_steps;
    omp_set_num_threads( 10);
   #pragma_omp_parallel
   {
     double x;
     #pragma omp for schedule(static) reduction( +:sum)
     for( i= 0 ; i<num_steps; ++ ) {
       x = (i+0.5)*step;
       sum = sum + 4.0/(1.0+x*x);
      #pragma omp atomic
      { sum += x ; }
     }
    }
    pi = sum * step;
}
```

beautiful & fast!!!

Private vs Shared

- Default behaviour:
  - outside the parallel region: shared
  - inside the parallel region: private
- Explicit control:
  - clause **shared(** *var*, **…)**
  - clause **private(** *var*, **…)**

Example:

```
int x=1, y=1, z=1, q=1;

#pragma parallel private( y,z) shared( q)
{
   x=2;
   y=2;
   q=z;
}
```

What values of x, y, z and q do we have *after* the parallel region?

x==2
y==1
z==1
q==<undefined>

Private vs Shared ctnd.

- Default behaviour:
  - outside the parallel region: shared
  - inside the parallel region: private
- Explicit control:
  - clause **shared(** *var*, **…)**
  - clause **private(** *var*, **…)**
  - clause **firstprivate(** *var*, **…)**

Example:

```
int x=1, y=1, z=1, q=1;

#pragma parallel private( y)  shared( q) firstprivate( z)
{
   x=2;
   y=2;
   q=z;
}
```

What values of x, y, z and q do we have *after* the parallel region?

x==2
y==1
z==1
q==1

Summary

- The most common pattern can easily be achieved
- There is much more (->www.openmp.org)
  - Tasks
  - Sections
  - Vector-instructions
  - Teams
  - …

Check it out ☺