Lecture 10

Programming Shared Memory IV

Controlling Thread, OpenMP (Open Multi-Processing)

Ceng505 *Parallel Computing* at December 13, 2010

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Contents

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- Pthreads allows the user to change the priority of the thread.
- Subsequent changes to attributes objects do not change the properties of entities created using the attributes object prior to the change.

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- To create an attributes object with the desired properties,
- we must first create an object with default properties and then modify the object as required.

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- **pthread_attr_default, pthread_attr_init**
- For most parallel programs, default thread properties are generally adequate.

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    - If the *count* is less than the total number of threads, the threads execute a *condition wait*.

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- A single integer is used to keep track of the number of threads that have reached the barrier.
  - If the *count* is less than the total number of threads, the threads execute a *condition wait*.
  - The last thread entering (and setting the count to the number of threads) wakes up all the threads using a condition broadcast.

Composite Synchronization Constructs II

The code for accomplishing this is as follows:

```
typedef struct {
    pthread_mutex_t count_lock;
    pthread_cond_t ok_to_proceed;
    int count;
} mylib_barrier_t;

void mylib_init_barrier(mylib_barrier_t *b) {
    b -> count = 0;
    pthread_mutex_init(&(b -> count_lock), NULL);
    pthread_cond_init(&(b -> ok_to_proceed), NULL);
}

void mylib_barrier (mylib_barrier_t *b, int num_threads) {
    pthread_mutex_lock(&(b -> count_lock));
    b -> count ++;
    if (b -> count == num_threads) {
        b -> count = 0;
        pthread_cond_broadcast(&(b -> ok_to_proceed));
    }
    else
        while (pthread_cond_wait(&(b -> ok_to_proceed),
            &(b -> count_lock)) != 0);
    pthread_mutex_unlock(&(b -> count_lock));
}
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- This implementation of a barrier can be speeded up using multiple barrier variables.

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- Such libraries (*slightly asynchronous* libraries) are more forgiving of synchronization errors in programs.
- On the other hand, **kernel threads** (threads supported by the kernel) and threads scheduled on multiple processors are less forgiving.
- The programmer must therefore **not make any assumptions** regarding the level of asynchrony in the threads library.

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- Once you create a thread, it is possible that the newly created thread actually runs to completion before the creating thread gets scheduled again.

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- Where possible, define and use group synchronizations and data replication.
- This can improve program performance significantly.
- **While these simple tips provide guidelines for writing error-free threaded programs, extreme caution must be taken to avoid race conditions and parallel overheads associated with synchronization.**

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- Conventional wisdom indicates that a large class of applications can be efficiently supported by **higher level constructs** (**or directives**)
- which rid the programmer of the mechanics of manipulating threads.
- Such **directive-based languages** have existed for a long time,
- but only recently have standardization efforts succeeded in the form of OpenMP.

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- This directive is responsible for **creating a group of threads**.

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- In Figure 1, one possible translation of an OpenMP program to a Pthreads program is shown.

The OpenMP Programming Model III

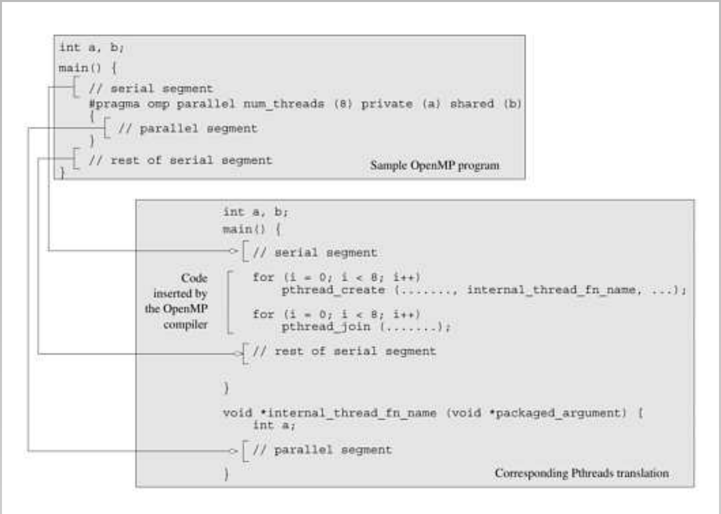

Figure: A sample OpenMP program along with its Pthreads translation that might be performed by an OpenMP compiler.

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  - The clause *firstprivate (variable list)* is similar to the private clause, except the values of variables on entering the threads are initialized to corresponding values before the parallel directive.
  - The clause *shared (variable list)* indicates that all variables in the list are shared across all the threads,
  - i.e., there is only one copy. Special care must be taken while handling these variables by threads to ensure serializability.

The OpenMP Programming Model V

```
#include <omp.h>
main ()  {
int var1, var2, var3;
Serial code
Beginning of parallel section. Fork a team of threads.
Specify variable scoping
#pragma omp parallel private(var1, var2) shared(var3)
  {
  Parallel section executed by all threads
  All threads join master thread and disband
  }
Resume serial code
}
***********************************************************
#include <omp.h>
int a,b,num_threads;
int main()
{
  printf("I am in sequential part.\n");
#pragma omp parallel num_threads (8) private (a) shared (b)
  {
    num_threads=omp_get_num_threads();
    printf("I am openMP parellized part and thread %d \n",
                                 omp_get_thread_num());
  }
}
```

The OpenMP Programming Model VI

Using the parallel directive;

```
#pragma omp parallel if (is_parallel == 1) num_threads(8)
            private (a) shared (b) firstprivate(c)
{
     /* structured block */
}
```

- Here, if the value of the variable *is_parallel* equals one, eight threads are created.

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- Furthermore, the value of each copy of c is initialized to the value of c before the parallel directive.

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- Each of these threads gets private copies of variables a and c, and shares a single value of variable b.
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- The clause *default (shared)* implies that, by default, a variable is shared by all the threads.

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- Furthermore, the value of each copy of c is initialized to the value of c before the parallel directive.
- The clause *default (shared)* implies that, by default, a variable is shared by all the threads.
- The clause *default (none)* implies that the state of each variable used in a thread must be explicitly specified.

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- Each of these threads gets private copies of variables a and c, and shares a single value of variable b.
- Furthermore, the value of each copy of c is initialized to the value of c before the parallel directive.
- The clause *default (shared)* implies that, by default, a variable is shared by all the threads.
- The clause *default (none)* implies that the state of each variable used in a thread must be explicitly specified.
- This is generally recommended, to guard against errors arising from unintentional concurrent access to shared data.

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- The usage of the *reduction* clause is *reduction (operator: variable list)*.
- This clause performs a reduction on the scalar variables specified in the list using the *operator*.
- The variables in the list are implicitly specified as being private to threads.
- The *operator* can be one of

```
+,  *,  -,  &,  |,  ^,  &&, and ||.
```

The OpenMP Programming Model VIII

Using the reduction clause;

```
#pragma omp parallel reduction(+: sum) num_threads(8)
 {
 /* compute local sums here */
  }
 /* sum here contains sum of all local instances of sums */
```

- In this example, each of the eight threads gets a copy of the variable *sum*.

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#pragma omp parallel reduction(+: sum) num_threads(8)
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- In this example, each of the eight threads gets a copy of the variable *sum*.
- When the threads exit, the sum of all of these local copies is stored in the single copy of the variable (at the master thread).

The OpenMP Programming Model IX

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- The parallel directive specifies that all variables except *npoints*, the total number of random points in two dimensions across all threads, are local.

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- The parallel directive specifies that all variables except *npoints*, the total number of random points in two dimensions across all threads, are local.
- Furthermore, the directive specifies that there are eight threads, and the value of sum after all threads complete execution is the sum of local values at each thread.
- A for loop generates the required number of random points (in two dimensions) and determines how many of them are within the prescribed circle of unit diameter.

The OpenMP Programming Model X

```
/* ******************************************************
 An OpenMP version of a threaded program to compute PI.
 ****************************************************** */

 #pragma omp parallel default(private) shared (npoints) \
                      reduction(+: sum) num_threads(8)
   {
    num_threads = omp_get_num_threads();
     sample_points_per_thread = npoints / num_threads;
     sum = 0;
     for (i = 0; i < sample_points_per_thread; i++) {
  rand_no_x =(double)(rand_r(&seed))/(double)((2<<14)-1);
  rand_no_y =(double)(rand_r(&seed))/(double)((2<<14)-1);
       if (((rand_no_x - 0.5) * (rand_no_x - 0.5) +
           (rand_no_y - 0.5) * (rand_no_y - 0.5)) < 0.25)
          sum ++;
     }
   }
```

Note that this program is <u>much easier</u> to write in terms of specifying creation and termination of threads compared to the corresponding POSIX threaded program.