CISC 372: Parallel Computing
OpenMP, Part 4

Stephen F. Siegel

Department of Computer and Information Sciences
University of Delaware

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Note:

- except for `barrier`, these do not impose barriers

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  - so explicit barrier is usually unnecessary
- main use: control accesses to shared variables to avoid data races
  - e.g., one thread writes, `barrier`, other threads read

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- typical use cases: print statements, debugging

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- common uses: printing, computation of max or min, ...
  - complex modifications to shared data
    - don't want any other thread to "see" the data in an intermediate state
    - all threads access the data through critical regions with the same name
    - very similar to use of locks or Java's `synchronized`

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- acceptable examples
  - `x++`, `x--`, `++x`, or `--x`
  - `x = x` *binop* *expr*
  - `x` *binop*`=` *expr*
  - `x =` *expr* *binop* `x`
- binary operators: `+`, `*`, `-`, `/`, `&`, `^`, `|`, `<<`, or `>>`
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- binary operators: `+`, `*`, `-`, `/`, `&`, `^`, `|`, `<<`, or `>>`
- no function calls or other kinds of expressions
- can be more efficient than `critical`
  - can take advantage of low-level atomic operations

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- similer to `single`, but recall:
  - `single` can choose any thread (not just master)
  - `single` has a barrier at end by default

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- considered "lower-level" primitives than the directive-based constructs
- type: `omp_lock_t`
- functions
  - `void omp_init_lock(omp_lock_t *lock);`
  - `void omp_destroy_lock(omp_lock_t *lock);`
  - `void omp_set_lock(omp_lock_t *lock);`
  - `void omp_unset_lock(omp_lock_t *lock);`

The threadprivate directive

- consider the program semiprivate.c. What is the output?

```
#include <stdio.h>
#include <omp.h>
int x = 99;
void f() {
  x=omp_get_thread_num();
}
int main() {
#pragma omp parallel private(x) num_threads(5)
  {
    int tid = omp_get_thread_num();
    f();
    printf("Thread %d: x = %d\n", tid, x);
  }
  printf("Final x = %d\n", x);
}
```

semiprivate.c: output

```
omp$ gcc-mp-4.8 -fopenmp semiprivate.c
omp$ ./a.out
Thread 1: x = -348111896
Thread 2: x = -348111896
Thread 3: x = -348111896
Thread 4: x = 19907219
Thread 0: x = 0
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Why?

- the `private` clause affects only references to the variable inside the construct (the static extent), not the region (dynamic extent).
- if you want `x` to be `private` everywhere, you need to use the `threadprivate` directive.

threadprivate.c

```
#include <stdio.h>
#include <omp.h>
int x;
#pragma omp threadprivate(x)
void f() {
  // this updates the private copy of x...
  x=omp_get_thread_num();
}
int main() {
#pragma omp parallel num_threads(5)
  {
    int tid = omp_get_thread_num();
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- you can even make the shared variable persist between parallel regions
  - certain requirements must be met
  - in particular, all the parallel regions in which variable is used must have same number of threads

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- you can even make the shared variable persist between parallel regions
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- note the variable must be initialized inside a parallel region before it is used

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  - performance often pretty good
    - sends and receives within a node implemented using `memcpy` or similar
- advantages of MPI+threads
  - might get better time performance
  - often uses less memory
    - in MPI everywhere, common data structures must be duplicated on every process, i.e., core
    - in MPI+threads, need only one copy of data structure on each node

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- different processes can request (and receive) different levels of support
- the interfaces for messages, etc., are the same whether or not there are multiple threads
  - hence a message sent by one thread on process p looks exactly the same as a message sent by another thread on p
  - there is no way for another process to tell which thread it came from
  - a message sent by p to another process q cannot target a particular thread on q
  - to participate in a collective routine, only one thread in p should call the collective functions

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The following function should be called instead of MPI_Init:

```
int MPI_Init_thread(int *argc, char ***argv,
                    int required, int *provided)
```

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```
int MPI_Is_thread_main(int *flag)
```

- true if calling thread is main thread, false otherwise