COMP/CS 605: Introduction to Parallel Computing
Topic : Code Basics/Parallel Software

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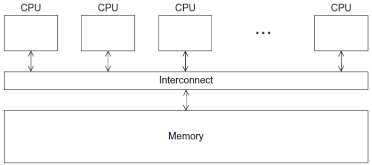
Table of Contents

Parallel Software for HPC

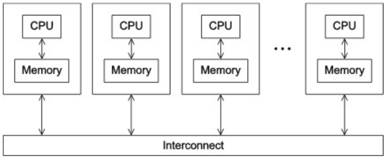
- Hardware and compilers continuously evolve
- Software must adapt to these changes
  - Compilers
  - Tool Libraries and API's
  - Performance Profiling
  - Complexity abstraction (how to synchronize 10^5 to 10^6 processors?)
- Key issues in writing software:
  - Thread coordination
  - Shared memory
  - Distributed memory

Memory Distribution Patterns

- In shared memory programs:
  - Start a single process and fork threads.
  - Threads carry out tasks.



- In distributed memory programs:
  - Start multiple processes.
  - Processes carry out tasks.



SPMD single program multiple data

- A SPMD programs consists of a single executable that can behave as if it were multiple different programs through the use of conditional branches.

```
  if ( I am thread process i )
       do something;
else
       do more interesting things;
```

Writing Parallel Programs

1. Divide the work among the processes/threads
   (a) so each process/thread gets roughly the same amount of work
   (b) and communication is minimized.
2. Arrange for the processes/threads to synchronize.
3. Arrange for communication among processes/threads.

```
double x[n], y[n];
...
for (i = 0; i < n; i++)
    x[i] += y[i];
```

Shared Memory

- Dynamic threads
  - Master thread waits for work, forks new threads, and when threads are done, they terminate
  - Efficient use of resources, but thread creation and termination is time consuming.
- Static threads
  - Pool of threads created and are allocated work, but do not terminate until cleanup.
  - Better performance, but potential waste of system resources.

Nondeterminism

```
. . .
printf ( "Thread %d > my_val = %d\n" ,
          my_rank , my_x ) ;
. . .
```

```
Thread 0 > my_val = 7
Thread 1 > my_val = 19
```

```
Thread 1 > my_val = 19
Thread 0 > my_val = 7
```

Nondeterminism

```
my_val = Compute_val ( my_rank ) ;
x += my_val ;
```

Time	Core 0	Core 1
0	Finish assignment to my_val	In call to Compute_val
1	Load x = 0 into register	Finish assignment to my_val
2	Load my_val = 7 into register	Load x = 0 into register
3	Add my_val = 7 to x	Load my_val = 19 into register
4	Store x = 7	Add my_val to x
5	Start other work	Store x = 19

Nondeterminism

- Race condition
- Critical section
- Mutually exclusive
- Mutual exclusion lock (mutex, or simply lock)

```
my_val = Compute_val ( my_rank ) ;
Lock(&add_my_val_lock ) ;
x += my_val ;
Unlock(&add_my_val_lock ) ;
```

busy-waiting

```
my_val = Compute_val ( my_rank ) ;
i f ( my_rank == 1)
    whi l e ( ! ok_for_1 ) ;  /* Busy−wait loop */
x += my_val ;  /* Critical section */
i f ( my_rank == 0)
    ok_for_1 = true ;  /* Let thread 1 update x
*/
```

message-passing

```
char message [ 1 0 0 ] ;
. . .
my_rank = Get_rank ( ) ;
i f ( my_rank == 1) {
    sprintf ( message , "Greetings from process 1" ) ;
    Send ( message , MSG_CHAR , 100 , 0 ) ;
} e l s e i f ( my_rank == 0) {
    Receive ( message , MSG_CHAR , 100 , 1 ) ;
    printf ( "Process 0 > Received: %s\n" ,
message ) ;
}
```

Partitioned Global Address Space Languages

```
shared i n t n = . . . ;
shared double x [ n ] , y [ n ] ;
private i n t i , my_first_element , my_last_element ;
my_first_element = . . . ;
my_last_element = . . . ;
/ * Initialize x and y  */
. . .
f o r ( i = my_first_element ; i <= my_last_element ; i++)
   x [ i ] += y [ i ] ;
```

Input and Output

- In distributed memory programs, only process 0 will access *stdin*. In shared memory programs, only the master thread or thread 0 will access *stdin*.
- In both distributed memory and shared memory programs all the processes/ threads can access *stdout* and *stderr*.

Input and Output

- However, because of the indeterminacy of the order of output to *stdout*, in most cases only a single process/thread will be used for all output to *stdout* other than debugging output.

- Debug output should always include the rank or id of the process/thread that's generating the output.

Input and Output

- Only a single process/thread will attempt to access any single file other than *stdin*, *stdout*, or *stderr*. So, for example, each process/thread can open its own, private file for reading or writing, but no two processes/threads will open the same file.