
Advanced OpenMP
Nested Parallelism
archer2
epcc

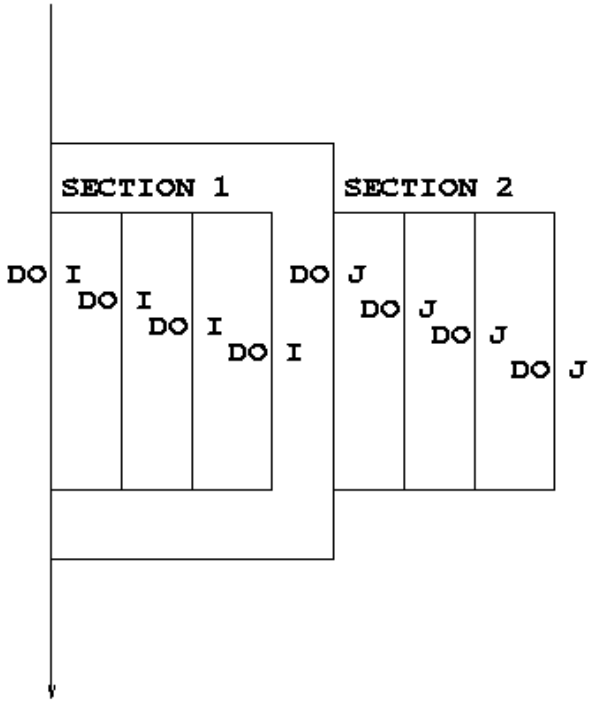
Nested parallelism

- Nested parallelism is supported in OpenMP.
- If a PARALLEL directive is encountered within another PARALLEL directive, a new team of threads will be created.
- This is enabled with the **`OMP_NESTED`** environment variable or the **`OMP_SET_NESTED`** routine.
- If nested parallelism is disabled, the code will still execute, but the inner teams will contain only one thread.

Nested parallelism (cont)

Example:

```
!$OMP PARALLEL PRIVATE(myid)
myid = omp_get_thread_num()
if (myid .eq. 0) then
!$OMP PARALLEL DO
      do i = 1,n
         x(i) = 1.0
      end do
elseif (myid .eq.1) then
!$OMP PARALLEL DO
      do j = 1,n
         y(j) = 2.0
      end do
endif
!$OMP END PARALLEL
```



Nested parallelism (cont)

Example:

```
#pragma omp parallel
{
   int myid = omp_get_thread_num();
   if (myid == 0) {
#pragma omp parallel for
     for(int i=0; i<N; i++){
       x[i] = 1.0;
     }
   } elseif(myid == 1){
#pragma omp parallel for
     for(int j=0; j<N; j++){
       y[j] = 2.0;
     }
   }
}
```

Nested parallelism (cont)

- Not often needed, but can be useful if the outer level does not contain enough parallelism

- Note: nested parallelism turns out to be hard to implement correctly without impacting performance.
  - usually disabled by default
  - don’t enable nested parallelism unless you are using it!

Controlling the number of threads

- Can use the environment variable

```
export OMP_NUM_THREADS=2,4
```

- Will use 2 threads at the outer level and 4 threads for each of the inner teams.

- Can use `omp_set_num_threads()` or the `num_threads` clause on the parallel region.

omp_set_num_threads()

- Useful if you want inner regions to use different numbers of threads:

```
CALL OMP_SET_NUM_THREADS(2)
!$OMP PARALLEL DO
      DO I = 1,4
CALL OMP_SET_NUM_THREADS(innerthreads(i))
!$OMP PARALLEL DO
         DO J = 1,N
            A(I,J) = B(I,J)*17
         END DO
      END DO
```

```
omp_set_num_threads(2);
#pragma omp parallel for
  for (int i=0; i<4; i++) {
    omp_set_num_threads(innerthreads[i]);
#pragma omp parallel for
     for (int j=0; j<N; j++) {
         a[j][i] = b[j][i] * 17;
     }
  }
```

- The value set overrides the value(s) in the environment variable OMP_NUM_THREADS

NUM_THREADS clause

- Another way to control the number of threads used at each level is with the NUM_THREADS clause:

```
!$OMP PARALLEL DO NUM_THREADS(2)
      DO I = 1,4
!$OMP PARALLEL DO NUM_THREADS(innerthreads(i))
         DO J = 1,N
            A(I,J) = B(I,J)
         END DO
      END DO
```

```
#pragma omp parallel for \
num_threads(2)
  for (int i=0; i<4; i++) {
#pragma omp parallel for \
num_threads(innerthreads[i])
     for (int j=0; j<N; j++) {
         a[j][i] = b[j][i] * 17;
     }
  }
```

- The value set in the clause overrides the value in the environment variable OMP_NUM_THREADS and that set by **omp_set_num_threads()**

More control….

- Can also control the maximum number of threads running at any one time.

```
export OMP_THREAD_LIMIT=64
```

- …and the maximum depth of nesting

```
export OMP_MAX_ACTIVE_LEVELS=2
```

or call

```
omp_set_max_active_levels()
```

Utility routines for nested parallelism

- `omp_get_level()`
  - returns the level of parallelism of the calling thread
  - returns 0 in the sequential part
- `omp_get_active_level()`
  - returns the level of parallelism of the calling thread, ignoring levels which are inactive (teams only contain one thread)
- `omp_get_ancestor_thread_num(level)`
  - returns the thread ID of this thread's ancestor at a given level
  - ID of my parent:
    `omp_get_ancestor_thread_num(omp_get_level()-1)`
- `omp_get_team_size(level)`
  - returns the number of threads in this thread's ancestor team at a given level

Nested loops

- For perfectly nested rectangular loops we can parallelise multiple loops in the nest with the `collapse` clause:

```
#pragma omp parallel for collapse(2)
for (int i=0; i<N; i++) {
  for (int j=0; j<M; j++) {
          .....
  }
}
```

- Argument is number of loops to collapse starting from the outside
- Will form a single loop of length NxM and then parallelise and schedule that.
- Useful if N is O(no. of threads) so parallelising the outer loop may not have good load balance
- More efficient than using nested teams

Synchronisation in nested parallelism

- Note that barriers (explicit or implicit) only affect the innermost enclosing parallel region.
- No way to have a barrier across multiple teams

- In contrast, critical regions, atomics and locks affect all the threads in the program
- If you want mutual exclusion within teams but not between them, need to use locks (or atomics).

Reusing this material