

Advanced OpenMP

Nested parallelism



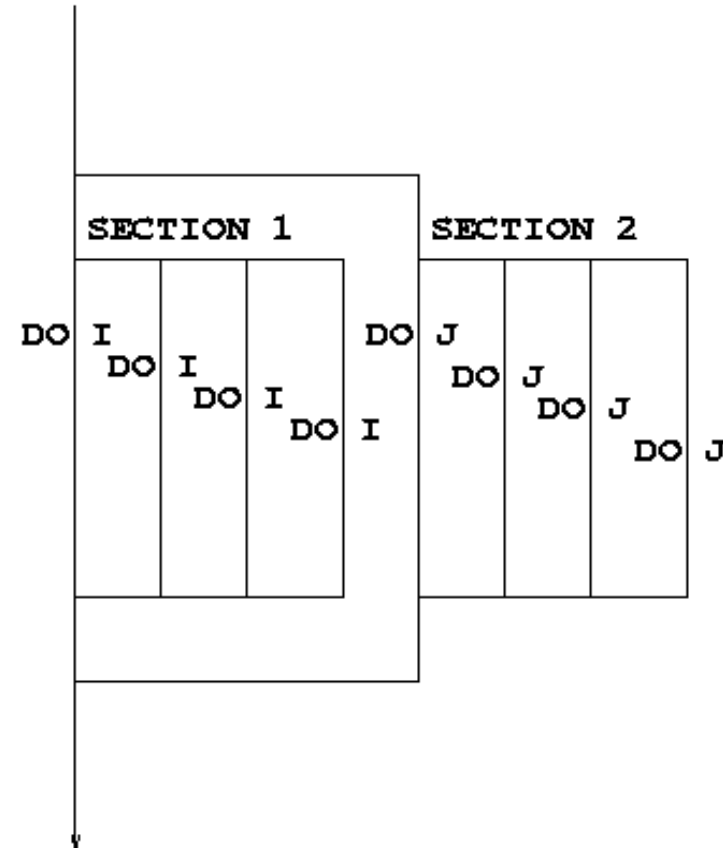
Nested parallelism

- 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)

- 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)
    END DO
END DO
```

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

NUM_THREADS clause

- One 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
```

- 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 $N \times M$ and then parallelise and schedule that.
- Useful if N is $O(\text{no. of threads})$ 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).

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