OpenMP Tasks

Computational Science II (CAAM 520)

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Motivation

So far all of our OpenMP code was loop based.

How can we implement more general multi-threaded algorithms?

Tasks

OpenMP tasks allow us to offload any "chunk" of work to a thread.

```
#pragma omp parallel
{
  #pragma omp single
  {
    #pragma omp task
    foo();

    #pragma omp task
    bar();
  }
}
```

Tasks

In this example `foo()` and `bar()` will be executed as tasks.

The OpenMP runtime environment schedules the tasks:

- Tasks can be executed by any thread.
- Tasks can be executed in any order.

→ Why do we need a `single` directive inside the parallel region?

Data environment for tasks

A task views variables as

- `firstprivate`, if the variable was `private` to the thread that created the task.
- `shared`, if the variable was `shared` in the thread that created the task.

Data environment for tasks

```
int i;

#pragma omp parallel
{
  int j;

  #pragma omp task
  {
    // Task has a "shared" view of i.
    // Task has a "firstprivate" copy of j.
  }
}
```

Data environment for tasks

The data environment can become complicated.

To be safe, use defaults!

```
int i;
#pragma omp parallel
{
  int j;
  #pragma omp task shared(i) firstprivate(j) \
                   default(none)
  {
    // The default(none) clause requires that
    // any variable is declared as shared or
    // firstprivate *explicitly*!
  }
}
```

Tasks and barriers

An OpenMP barrier enforces the completion of ***all*** incomplete tasks that were created in the current parallel environment.

```
#pragma omp parallel
{
  #pragma omp single
  for (int i = 0; i < 4; i++) {
    #pragma omp task
    do_work(i);
  }
  #pragma omp barrier

  // All tasks are complete at this point.
}
```

The `taskwait` directive

The `taskwait` directive enforces the completion of all ***child*** tasks.

It does not synchronize threads in any other way, i.e., it is weaker than a barrier.

Tasks and dependencies

Why do we ***need*** tasks?

Why not just use the `single` directive?

```
#pragma omp parallel
{
  #pragma omp single
  foo();

  #pragma omp single
  bar();
}
```

Tasks and dependencies

OpenMP allows us to express dependencies between tasks:

```
#pragma omp parallel
{
  #pragma omp single
  {
    #pragma omp task depend(out:x)
    x = foo();
    // First task must finish before
    // this task can run.
    #pragma omp task depend(in:x)
    bar(x);
  }
}
```

Tasks and dependencies

Dependencies can be expressed by adding `depend(type:list)` clauses to the `task` directive, where

- `type` can be `in`, `out`, `inout`, among other options, and
- `list` is a comma-separated list of variables.

→ Instead of individual variables, we can also specify ranges within arrays in the format `my_array[start:length]`.