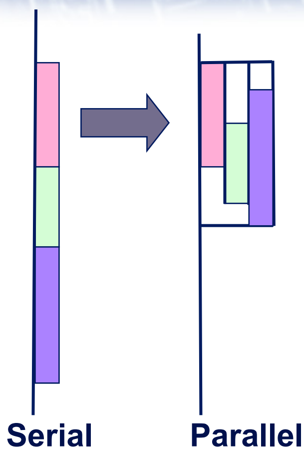
Threaded Programming

Lecture 6: Tasks

What are tasks?

- Tasks are independent units of work
- Tasks are composed of:
  - code to execute
  - data environment
- Threads are assigned to perform the work of each task.
- The runtime system will either:
  - Defer tasks for later execution.
  - Execute the tasks immediately.



OpenMP tasks

- The task construct defines a section of code
- Inside a parallel region, a thread encountering a task construct will package up the task for execution
- Some thread in the parallel region will execute the task at some point in the future
- Tasks can be nested: i.e. a task may itself generate tasks.

`task` directive

Syntax:

Fortran:

```
!$OMP TASK [clauses]
    structured block
!$OMP END TASK
```

C/C++:

```
#pragma omp task [clauses]
    structured-block
```

When/where are tasks complete?

- At thread barriers (explicit or implicit)
  - applies to all tasks generated in the current parallel region up to the barrier
- At taskwait directive
  - i.e. Wait until all tasks defined in the current task have completed.
  - Fortran: `!$OMP TASKWAIT`
  - C/C++: `#pragma omp taskwait`
  - Note: applies only to tasks generated in the current task, not to "descendants" .

Example

```
p = listhead ;
while (p) {
  process (p);
  p=next(p) ;
}
```

- Classic linked list traversal
- Do some work on each item in the list
- Assume that items can be processed independently
- Cannot use an OpenMP loop directive

Parallel pointer chasing

```
#pragma omp parallel
{
  #pragma omp single private(p)
   {
    p = listhead ;
    while (p) {
       #pragma omp task firstprivate(p)
             {
               process (p);
             }
       p=next (p) ;
     }
   }
}
```

Only one thread packages tasks

makes a copy of **p** when the task is packaged

Parallel pointer chasing on multiple lists

```
#pragma omp parallel
{
   #pragma omp for private(p)
   for ( int i =0; i <numlists ; i++) {
       p = listheads [ i ] ;
       while (p ) {
       #pragma omp task firstprivate(p)
           {
             process (p);
           }
       p=next (p ) ;
       }
   }
}
```

All threads package tasks

Data Sharing

- The default for tasks is usually firstprivate, because the task may not be executed until later (and variables may have gone out of scope).
- Variables that are shared in all constructs starting from the innermost enclosing parallel construct are shared.

```
#pragma omp parallel shared(A) private(B)
{
    ...
#pragma omp task
    {
        int C;
        compute(A, B, C);
    }
}
```

A is shared
B is firstprivate
C is private

Data sharing (cont.)

- Things can get rather complicated with nested tasks….

```
#pragma omp task private(B)
{
    B = ...
#pragma omp task shared (B)
    {
        compute(B);
    }
    ...
#pragma omp taskwait
}
```

- Every outer task has its own copy of B
- All inner tasks use their parent task's copy of B
- Taskwait ensures these don't go out of scope….

Example: postorder tree traversal

- Binary tree of tasks
- Traversed using a recursive function
- A task cannot complete until all tasks below it in the tree are complete

```
void postorder(node *p) {
    if (p->left)
      #pragma omp task
        { postorder(p->left); }
    if (p->right)
      #pragma omp task
        { postorder(p->right); }
    #pragma omp taskwait
    process(p->data);
}
```

Parent task suspended until children tasks complete

Task switching

- Certain constructs have task scheduling points at defined locations within them
- When a thread encounters a task scheduling point, it is allowed to suspend the current task and execute another (called *task switching*)
- It can then return to the original task and resume

Task switching

```
#pragma omp single
{
  for (i=0; i<ONEZILLION; i++)
    #pragma omp task
      process(item[i]);
}
```

- Risk of generating too many tasks
- Generating task will have to suspend for a while
- With task switching, the executing thread can:
  - execute an already generated task (draining the "*task pool*")
  - execute the encountered task

Using tasks

- Getting the data attribute scoping right can be quite tricky
  - default scoping rules different from other constructs
  - as ever, using `default(none)` is a good idea
- Don't use tasks for things already well supported by OpenMP
  - e.g. standard do/for loops
  - the overhead of using tasks is greater
- Don't expect miracles from the runtime
  - best results usually obtained where the user controls the number and granularity of tasks

Parallel pointer chasing again

```
#pragma omp parallel
{
  #pragma omp single private(p)
   {
    p = listhead ;
    while (p) {
       #pragma omp task firstprivate(p)
             {
               process (p,nitems);
             }
         for (i=0; i<nitems &&p; i++){
            p=next (p) ;
         }
      }
   }
}
```

process **nitems** at a time

skip **nitems** ahead in the list

Exercise

- Mandelbrot example using tasks.