OpenMP Tasks

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Motivation for the `task` Primitive

- We have seen
  - **`parallel`** (creates a team of threads)
  - **`for`** inside **`parallel`**
    - And **`parallel for`** as a short-form
  - **`sections`** inside parallel
- The **`for`** construct works on parallelizing bodies of loop
  - Identical code (identical work, mostly) on different data
  - The number of iterations (i.e., number of similar tasks) must be fixed
- What about situations when the number of pieces of work is not known a-priory?
  - E.g., traverse list, graph, or tree and do some computation for each node
  - E.g., generate parallelizable work as you execute existing parallel work
- And you want the system to automate work-sharing

The Task Construct

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

- Conceptually, this enqueues an entry corresponding to the “task” of executing the structured-block into a pool/queue of tasks, from which any thread in the team can execute it

```
#pragma omp taskwait
```

- Wait for the completion of child tasks of current task
  - The current task suspends until then

Tasking

- OpenMP task is generated when task directive is encountered
  - and the "`if`" clause evaluates to true, if it exists
- Task directive defines the code being executed and the data environment (shared/firstprivate, etc.)
- Task execution can be
  - Immediate
  - Deferred
- A deferred task is not necessarily executed by the thread that creates it
  - Any member of the current team may execute it

Tasking Example

```
int main( )
{
    int x = 0;
    int n = 30;
    #pragma omp parallel shared(n, x)
    {
        #pragma omp single
        x = fib(n);
    }

    printf("fib(%d) = %d\n", n, x);
    return 0;
}
```

Tasking Example

```
int main( )
{
    int x
    int n
    #pragm
    {
        #p
        x
    }

    printf
    return
}
```

```
int fib(int n) {
    int i, j;
    if (n == 0)
        return 0;
    else if (n <= 2)
        return 1;
    else {
        #pragma omp task shared(i) if (n > 20)
        i = fib(n-1);
        #pragma omp task shared(j) if (n > 20)
        j = fib(n-2);
        #pragma omp taskwait

        return i+j;
    }
}
```

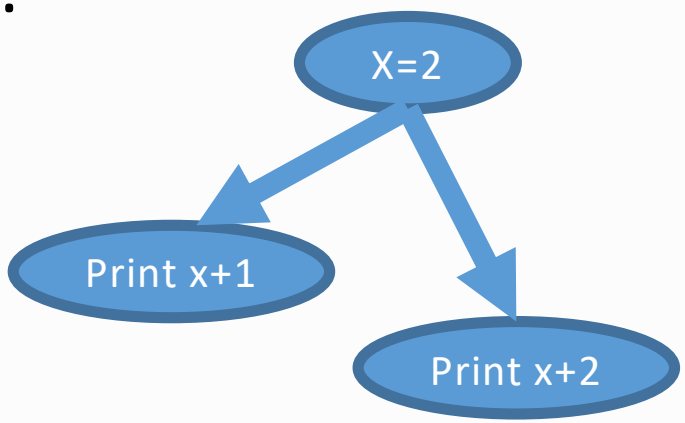
Clauses for the `task` Directive

- The usual – **`firstprivate`**,**`private, shared, default`**
- **`if –`** allows user-specified condition for whether to spawn task or just do the work
- **`untied`** – the task created can be executed by different threads over a period of time
  - (I.e., it can "yield" the thread to allow it do other things)
- **`priority(value)–`** hint to the system about picking which task to work on
  - Higher number is higher priority
    - (This may be reverse of what some of you may expect, from Unix priorities, for example)
- **`depend(type:list)– in, out, inout`**

depend Clause and Creating a DAG of Tasks

- Examples from the OpenMP 4.5 Example document:

```
#include <stdio.h>
int main(){
    int x = 1;
    #pragma omp parallel
    #pragma omp single
    {     #pragma omp task shared(x) depend(out: x)
          x = 2;
          #pragma omp task shared(x) depend(in: x)
          printf("x + 1 = %d. ", x+1);
          #pragma omp task shared(x) depend(in: x)
          printf("x + 2 = %d\n", x+2);
    }
    return 0;
}
```



From

OpenMP Application Programming Interface: Examples

https://www.openmp.org/specifications/

Exercise

```
int f(a){
      x = g(a);
      y = h(a);
      z = foo(x,y);
      t = bar(x);
      u = last(z,t);
    }
```

Add task primitives with **depend** clauses for each of the statements, so that they compute the same results as the sequential code would, assuming none of the functions change any global variables

depend Clause with Array Sub-Ranges

```
// Assume BS divides N perfectly
void matmul_depend(int N, int BS, float A[N][N], float B[N][N], float C[N][N])
{
    int i, j, k, ii, jj, kk;
    for (i = 0; i < N; i+=BS) {
        for (j = 0; j < N; j+=BS) {
            for (k = 0; k < N; k+=BS) {
// Note 1: i, j, k, A, B, C are firstprivate by default
// Note 2: A, B and C are just pointers
#pragma omp task private(ii, jj, kk) \
         depend ( in: A[i:BS][k:BS], B[k:BS][j:BS] ) \
         depend ( inout: C[i:BS][j:BS] )
             for (ii = i; ii < i+BS; ii++ )
                 for (jj = j; jj < j+BS; jj++ )
                     for (kk = k; kk < k+BS; kk++ )
                         C[ii][jj] = C[ii][jj] + A[ii][kk] * B[kk][jj];
                     }
                 }
             }
         }
```

From

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Exercise: Gauss-Seidel Using Tasks

- Recall the formulation with row decomposition and tiles of width w that we did earlier (using flush primitive)
- Redo that with tasks and dependences on the tiles
- Analyze cache performance issues