

OpenMP Tasking Explained

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What Was Missing ?



Before OpenMP 3.0

- Constructs worked well for many cases
- But OpenMP's Big Brother had to see everything
 - Loops with a known length at run time
 - Finite number of parallel sections
 -
- This didn't work well with certain common problems
 - Linked lists and recursive algorithms being the cases in point
- Often, a solution was feasible, but ugly at best

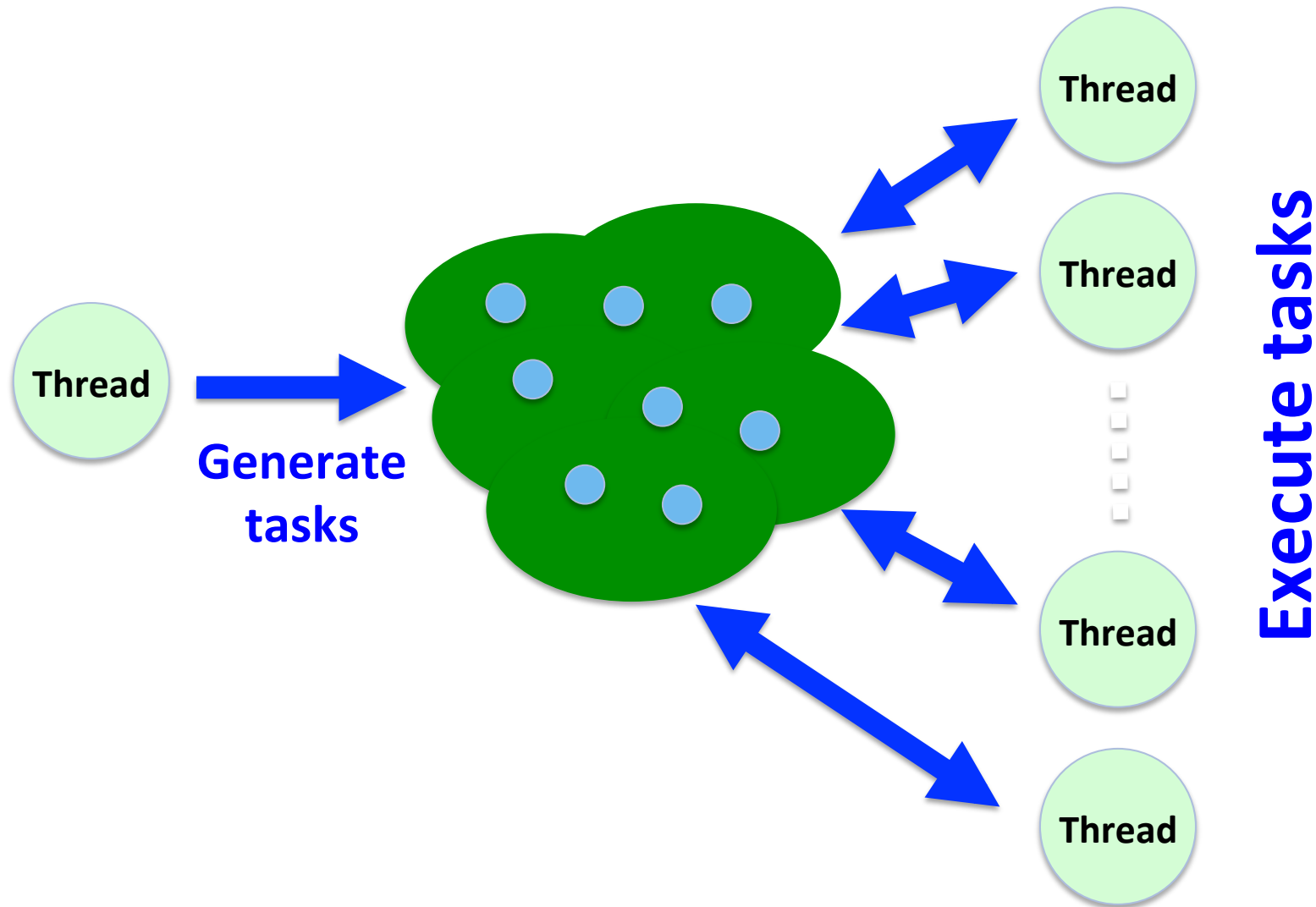
Today's All New Episode

TASKING

Tasking in OpenMP

- Tasking was introduced in OpenMP 3.0
- Until then it was impossible to efficiently and easily implement certain types of parallelism
- The initial functionality was very simple by design
 - The idea was (and still) is to augment tasking as we collectively gain more insight and experience
- Note that tasks can be nested
 - But not for the faint of heart

The Tasking Concept In OpenMP



Who Does What And When ?



Developer

Use a pragma to specify where the tasks are

(The assumption is that all tasks can be executed independently)

OpenMP runtime system

- When a thread encounters a task construct, a new task is generated
- The moment of execution of the task is up to the runtime system
- Execution can either be immediate or delayed
- Completion of a task can be enforced through **task synchronization**

The Tasking Construct

```
#pragma omp task
```

```
!$omp task
```

Defines a task

Task Synchronization

There are two task synchronization constructs

#pragma omp barrier

```
#pragma omp barrier
```

```
!$omp barrier
```

#pragma omp taskwait

```
#pragma omp taskwait
```

```
!$omp taskwait
```

Task Completion



Explicitly wait on the completion of child tasks:

```
#pragma omp taskwait
```

```
!$omp flush taskwait
```

Tasking Explained By Ways Of One Example



A Simple Plan

Your Task for Today:

***Write a program that prints either “A race car” or
“A car race” and maximize the parallelism***

Tasking Example/1

```
#include <stdlib.h>
#include <stdio.h>
```

```
int main(int argc, char *argv[]) {

    printf("A ");
    printf("race ");
    printf("car ");

    printf("\n");
    return(0);
}
```

```
$ cc -fast hello.c
$ ./a.out
A race car
$
```

What will this program print ?

Tasking Example/2

```
#include <stdlib.h>
#include <stdio.h>

int main(int argc, char *argv[]) {

    #pragma omp parallel
    {
        printf("A ");
        printf("race ");
        printf("car ");

    } // End of parallel region

    printf("\n");
    return(0);
}
```

*What will this program print
using 2 threads ?*

Tasking Example/3

```
$ cc -xopenmp -fast hello.c  
$ export OMP_NUM_THREADS=2  
$ ./a.out  
A race car A race car
```

Note that this program could (for example) also print

“A A race race car car” or

“A race A car race car”, or

“A race A race car car”, or

.....

But I have not observed this (yet)

Tasking Example/4

```
#include <stdlib.h>
#include <stdio.h>

int main(int argc
```

*What will this program print
using 2 threads ?*

```
    #pragma omp parallel
    {
        #pragma omp single
        {
            printf("A ");
            printf("race ");
            printf("car ");
        }
    } // End of parallel region

    printf("\n");
    return(0);
}
```


Tasking Example/5

```
$ cc -xopenmp -fast hello.c  
$ export OMP_NUM_THREADS=2  
$ ./a.out  
A race car
```

***But of course now only 1
thread executes***

Tasking Example/6

```
int main(int argc, char *argv[]) {  
    #pragma omp parallel  
    {  
        #pragma omp single  
        {  
            printf("A ");  
            #pragma omp task  
            {printf("race ");}  
            #pragma omp task  
            {printf("car ");}  
        }  
    } // End of parallel region  
  
    printf("\n");  
    return(0);  
}
```

***What will this program print
using 2 threads ?***

Tasking Example/7

```
$ cc -xopenmp -fast hello.c
$ export OMP_NUM_THREADS=2
$ ./a.out
A race car
$ ./a.out
A race car
$ ./a.out
A car race
$
```

***Tasks can be executed in
arbitrary order***

Another Simple Plan



You did well and quickly, so here is a final task to do

***Have the sentence end with “is fun to watch”
(hint: use a print statement)***

Tasking Example/8

```
int main(int argc, char *argv[]) {  
    #pragma omp parallel  
    {  
        #pragma omp single  
        {  
            printf("A ");  
            #pragma omp task  
            {printf("race ");}  
            #pragma omp task  
            {printf("car ");}  
            printf("is fun to watch ");  
        }  
    } // End of parallel region  
  
    printf("\n");  
    return(0);  
}
```

***What will this program print
using 2 threads ?***

Tasking Example/9

```
$ cc -xopenmp -fast hello.c  
$ export OMP_NUM_THREADS=2  
$ ./a.out
```

```
A is fun to watch race car  
$ ./a.out
```

```
A is fun to watch race car  
$ ./a.out
```

```
A is fun to watch car race  
$
```

Tasks are executed at a task execution point

Tasking Example/10

```
int main(int argc, char
#pragma omp parallel
{
    #pragma omp single
    {
        printf("A ");
        #pragma omp task
        {printf("car ");}
        #pragma omp task
        {printf("race ");}
        #pragma omp taskwait
        printf("is fun to watch ");
    }
} // End of parallel region

printf("\n");return(0);
}
```

*What will this program
print using 2 threads ?*

Tasking Example/11

```
$ cc -xopenmp -fast hello.c
$ export OMP_NUM_THREADS=2
$ ./a.out
$
A car race is fun to watch
$ ./a.out
A car race is fun to watch
$ ./a.out
A race car is fun to watch
$
```

Tasks are executed first now

Thank You And Stay Tuned !

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More About Tasking

- As the computation progresses, the work performed per task may shrink
 - Recursive algorithms are an example
 - This is where the **final** clause may come handy
- The data environment can also grow too much
 - This is why the **mergeable** clause has been added

Example – Linked List/1

```
.....  
while(my_pointer) {  
  
    (void) do_independent_work (my_pointer);  
    my_pointer = my_pointer->next ;  
} // End of while loop  
.....
```

***Hard to do before tasking:
First count number of iterations, then
convert while loop to for loop***

Example – Linked List/2

- Walking through the linked list is a serial process
 - Scan each entry until the NULL pointer has been hit
- How do we create the tasks then ?
- The idea is actually quite simple:
 - Use the **single** construct : one thread generates the tasks
 - All other threads execute the tasks as they become available

Example – Linked List/3

```
my_pointer = listhead;
```

```
#pragma omp parallel  
{
```

```
    #pragma omp single  
    {
```

```
        while(my_pointer)
```

```
            #pragma omp task firstprivate(my_pointer)  
            {
```

```
                (void) do_independent_work (my_pointer);
```

```
            }
```

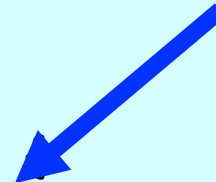
```
            my_pointer = my_pointer->next ;
```

```
        }
```

```
    } // End of single
```

```
} // End of parallel region
```

*OpenMP Task is specified here
(executed in parallel)*



Example – Linked List/4

*Can eliminate
a barrier*

```
my_pointer = listhead;

#pragma omp parallel
{
    #pragma omp single nowait
    {
        while(my_pointer) {
            #pragma omp task firstprivate(my_pointer)
            {
                (void) do_independent_work (my_pointer);
            }
            my_pointer = my_pointer->next ;
        }
    } // End of single - no implied barrier (nowait)
} // End of parallel region - implied barrier
```

Main Tasking Extensions in 4.0



■ The **depend** clause to support task dependences

- Forces additional constraints on task scheduling
- Expressed through: list item(s) + dependence type
- Dependence types are: in, out and inout

■ The **taskgroup** construct

- Specifies to wait on completion of child tasks and their descendant tasks
- Note: taskwait only joins direct child tasks