OpenMP Case Study: Bubble Sort

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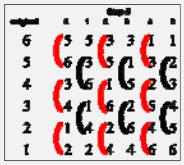
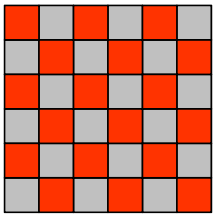


A Special Parallel Design Pattern

Implementing a Bubble Sort in parallel is an example of a special design pattern called ***Even-Odd***, or ***Red-Black***



Non-threaded Bubble Sort

```
#include <algorithm>
        . . .
for( int i = 0; i < N; i++ )
{
        bool stop = true;

        for( int j = 0; j < N-1; j++ )
        {
                if( B[ j ] > B[ j+1 ] )
                {
                        std::swap( B[ j ], B[ j+1 ] );
                        stop = false;
                }
        }

        if( stop )
                break;
}
```

N = 6

original	Step # 0	1	2	3	4
6	5	4	3	2	1
5	4	3	2	1	2
4	3	2	1	3	3
3	2	1	4	4	4
2	1	5	5	5	5
1	6	6	6	6	6

Why Can't This Version of the Bubble Sort Be Run in Parallel?

```
#include <algorithm>
        . . .
for( int i = 0; i < N; i++ )
{
        bool  stop = true;

        if( B[ 0 ] > B[ 1 ] )
        {
                std::swap( B[ 0 ], B[ 1 ] );
                stop = false;
        }

        if( B[ 1 ] > B[ 2 ] )
        {
                std::swap( B[ 1 ], B[ 2 ] );
                stop = false;
        }

        if( B[ 2 ] > B[ 3 ] )
        {
                std::swap( B[ 2 ], B[ 3 ] );
                stop = false;
        }

        . . .

        if( stop )
                break;
}
```

Let's unroll the inner (j) loop so we can see what the for-loop really looks like.

Suppose each of these if-blocks gets assigned to a different thread (remember that OpenMP tries to assign different for-loop passes to different threads).

Remembering that we have no explicit control over thread scheduling, notice that both the first and second if-blocks are both reading from and writing to **B[1]**. There is no synchronization to control in which order this is happening. We have a classic **Race Condition**.

The solution is, in one pass, allow a single thread access to B[0] and B[1], another thread access to B[2] and B[3], another thread access to B[4] and B[5], etc.

Then, in the next pass, allow a single thread access to B[1] and B[2], another thread access to B[3] and B[4], another thread access to B[5] and B[6], etc.

Threaded Bubble Sort

```
#include <algorithm>
        . . .
for(  int i = 0;  i < N;  i++ )
{
        int first = i % 2;      // 0 if i is 0, 2, 4, ...
                                // 1 if i is 1, 3, 5, ...

        #pragma omp parallel for default(none),shared(A,first)

        for(  int j = first;  j < N-1;  j += 2  )
        {
                if( A[ j ] > A[ j+1 ] )
                {
                        std::swap( A[ j ], A[ j+1 ] );
                }
        }
}
```

N = 6

original	Step # 0	1	2	3	4	5
6	5	5	3	3	1	1
5	6	3	5	1	3	2
4	3	6	1	5	2	3
3	4	1	6	2	5	4
2	1	4	2	6	4	5
1	2	2	4	4	6	6

A Comparison

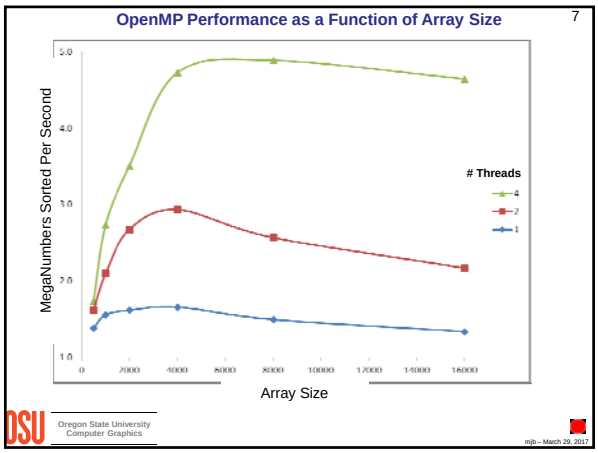
N = 6

original	Step # 0	1	2	3	4
6	5	4	3	2	1
5	4	3	2	1	2
4	3	2	1	3	3
3	2	1	4	4	4
2	1	5	5	5	5
1	6	6	6	6	6

Non-threaded

original	Step # 0	1	2	3	4	5
6	5	5	3	3	1	1
5	6	3	5	1	3	2
4	3	6	1	5	2	3
3	4	1	6	2	5	4
2	1	4	2	6	4	5
1	2	2	4	4	6	6

Threaded


OpenMP Performance as a Function of Array Size
7
MegaNumbers Sorted Per Second
5.0
4.0
3.0
2.0
1.0
0
2000
4000
6000
8000
10000
12000
14000
16000
Array Size
Threads
4
2
1
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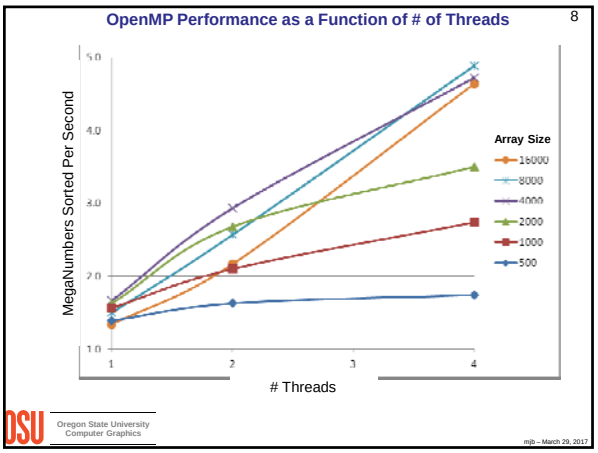
OpenMP Performance as a Function of # of Threads
8
MegaNumbers Sorted Per Second
5.0
4.0
3.0
2.0
1.0
1
2
3
4
Threads
Array Size
16000
8000
4000
2000
1000
500
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