

Homework 1

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1 Problem 1

What are the identity values for the operators: &&, ||, |, ^?

```
&& : 1
||  : 0
|   : 0
^   : 0
```

2 Problem 2

Suppose OpenMP did not have the reduction clause. Show how to implement an efficient parallel reduction by adding a private variable and using the critical pragma.

```
/* File:      problem2.cpp
 * Purpose: Alternates sign of integer added to sum
 *
 *           sum = 0 + 1 + -2 + 3 + -4...
 *
 * Compile: g++ -Wall -fopenmp -o problem2 problem2.cpp -std=c++11
 *          g++ -Wall -fopenmp -o problem2 problem2.cpp -DDEBUG -std=c++11
 * Run:     ./problem2
 *
 * Input:    none
 * Output:   Times for each of the three runs
 *
 * Notes:
 * 1.        If ran with the -DDEBUG flag you can see what the sum should
 *           be based on n
 *
 */

#include <inttypes.h> // Better integer functionality
#include <stdio.h>    // Printing to console
#include <omp.h>      // Multithreading
#include <chrono>     // High precision clock

using namespace std::chrono;

// Global
uint8_t  thrds  = omp_get_num_procs();

int main(int argc, char* argv[]) {
    uint8_t times = 20;
    high_resolution_clock::time_point t1 = high_resolution_clock::now();
    high_resolution_clock::time_point t2 = high_resolution_clock::now();
    duration<double> no_omp_time = duration_cast<duration<double>>\
        (high_resolution_clock::now() - high_resolution_clock::now());
    duration<double> omp_time = duration_cast<duration<double>>\
        (high_resolution_clock::now() - high_resolution_clock::now());
    duration<double> no_reduc_time = duration_cast<duration<double>>\
        (high_resolution_clock::now() - high_resolution_clock::now());
    for(uint8_t j = 0; j < times; ++j)
```

```

{
    uint64_t    n        = 80000000,
               k        = 0;
    int64_t     sum      = 0;

    // RESET for baseline
    t1 = high_resolution_clock::now();

    for (k = 0; k < n; ++k)
    {
        sum += ((k & 1) == 0 ? 1.0 : -1.0) * k;
    }

    t2 = high_resolution_clock::now();
    no_omp_time += duration_cast<duration<double>>(t2 - t1);
#ifdef DEBUG
    if (j == 0){
        printf("No OMP sum      : %" PRIi64 "\n", sum);
    }
#endif

    // RESET for reduction + omp
    sum = 0;
    t1 = high_resolution_clock::now();

    #pragma omp parallel for num_threads(thrds) reduction(+: sum) private(k)
    for (k = 0; k < n; ++k)
    {
        sum += ((k & 1) == 0 ? 1.0 : -1.0) * k;
    }

    t2 = high_resolution_clock::now();
    omp_time += duration_cast<duration<double>>(t2 - t1);
#ifdef DEBUG
    if (j == 0){
        printf("OMP sum          : %" PRIi64 "\n", sum);
    }
#endif

    // RESET for no reduction
    sum = 0;
    k = 0;
    t1 = high_resolution_clock::now();

    #pragma omp parallel num_threads(thrds)
    {
        int64_t thread_sum = 0;
        #pragma omp for
        for(uint64_t i = k; i < n; ++i){
            // Locally (privately) runs this
            thread_sum += ((i & 1) == 0 ? 1.0 : -1.0) * i;
        }
    }
}

```

```

        #pragma omp critical
        sum += thread_sum;
    }

    t2 = high_resolution_clock::now();
    no_reduc_time += duration_cast<duration<double>>(t2 - t1);
#ifdef DEBUG
    if (j == 0){
        printf("No Reduc sum : %" PRIi64 "\n", sum);
    }
#endif
}

printf("Averages over %" PRIu8 " runs:\n", times);
printf("No OMP      : %.14f\n", no_omp_time.count() / times);
printf("OMP        : %.14f\n", omp_time.count() / times);
printf("No Reduc   : %.14f\n", no_reduc_time.count() / times);

return 0;
}

```

```

kyle@HW1$ g++ -Wall -fopenmp -o problem2 problem2.cpp -DDEBUG -std=c++11
kyle@HW1$ ./problem2
No OMP sum : -40000000
OMP sum : -40000000
No Reduc sum : -40000000
Averages over 20 runs:
No OMP : 0.40371242310000
OMP : 0.06024930730000
No Reduc : 0.06116008355000
kyle@HW1$

```

Figure 1: Example debug output.

```

kyle@HW1$ ./problem2
Averages over 20 runs:
No OMP : 0.40169680075000
OMP : 0.05187247365000
No Reduc : 0.05121839645000
kyle@HW1$ ./problem2
Averages over 20 runs:
No OMP : 0.40076352375000
OMP : 0.05140341830000
No Reduc : 0.05126510895000
kyle@HW1$ ./problem2
Averages over 20 runs:
No OMP : 0.40068608615000
OMP : 0.05138620015000
No Reduc : 0.05121338355000

```

Figure 2: Better performance without reduction.

As can be seen in the figures the sums are performing as expected. An interesting, and expected outcome is that in Figure 1 it takes 0.06 seconds to run *OMP* and *No Reduc* but in Figure 2 it takes 0.05 seconds. The *No OMP* takes 0.40 seconds regardless. The reason for this behavior is that *OMP* uses the cores you give it and at the time of recording the first figure the browser was open and running a video. When I recorded the second Figure I had closed my browser to maximize performance for multi-core processing. The *No OMP* section of code was only running on one core, so it did not care that I had a video playing.

3 Problem 3

3.1 Problem 3a

3.2 Problem 3b

This code section is not suitable for OpenMP because of the `&&` operator in comparison. Per the [OpenMP documentation](#) §2.6, p53:

test-expr One of the following:
 var relational-op b
 b relational-op var

relational-op One of the following:
 <
 <=
 >
 >=

3.3 Problem 3c

This code can be ran with OMP but it is dependent on whether or not *foo()* is threadsafe.

3.4 Problem 3d

asdf

3.5 Problem 3e

asdf

3.6 Problem 3f

asdf

3.7 Problem 3g

asdf

3.8 Problem 3h

asdf

4 Problem 4

asdf

5 Problem 5

If the address of the nodes in a hypercube has n bits. How many nodes can it be at the most and how many edges does each node have? Give an algorithm that routes a message from node u to node v in this k -node hypercube in no more than $\log(k)$ steps.

Hypercubes are generalized by dimensionality. A hypercube address containing n -bits will exist in n dimensions (d). The maximum number of nodes is determined by d , and is defined as 2^d . A trait of hypercubes is that each node will have d edges. The total amount of edges would be defined as $d * 2^{d-1}$. The number of nodes you have to travel between u and v is equal to the number of differing bits.

For example:

000	=>	111	: 3
001	=>	100	: 2
110	=>	011	: 2

Therefore a traversal algorithm should be:

if *understand* **then**

 go to next section;

 current section becomes this one;

else

 go back to the beginning of current section;

end

Algorithm 1: How to write algorithms

6 Graduate Assignment

Do a search on Shuffle-exchange network topology. Draw the network with 16 processor nodes (carefully numbering each node binary and showing what is a shuffle link, what is an exchange link). If k is the number of digits in the binary address, how many nodes (n) are there? With n nodes what is the diameter (d) of the networks, the bisection width (b) and how many edges/node?

When you first drew a shuffle-exchange network (also sometimes called butterfly network) I immediately thought that looked like a sorter I came up with in 300. I later learned that sort wasn't something I had uniquely developed and was in fact a [bitonic sort](#).