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CS 61C Fall 2018

Parallelism, SDS

Discussion 9: October 22, 2018

1 Thread-Level Parallelism

As powerful as data level parallelization is, it can be quite inflexible, as not all applications have data that can be vectorized. Multithreading, or running a single piece of software on multiple hardware threads, is much more powerful and versatile. OpenMP provides an easy interface for using multithreading within C programs. Some examples of OpenMP directives:

The `parallel` directive indicates that each thread should run a copy of the code within the block. If a for loop is put within the block, **every** thread will run every iteration of the for loop.

```
#pragma omp parallel {
    ...
}
```

The `parallel for` directive will split up iterations of a for loop over various threads. Every thread will run **different** iterations of the for loop. The following two code snippets are equivalent.

```
#pragma omp parallel for
for (int i = 0; i < n; i++) {
    ...
}
```

```
#pragma omp parallel {
#pragma omp for
    for (int i =0; i < n; i++) { ... }
}
```

There are two functions you can call that may be useful to you:

- `int omp_get_thread_num()` will return the number of the thread executing the code
- `int omp_get_num_threads()` will return the number of total hardware threads executing the code

1.1 For each question below, state and justify whether the program is **sometimes incorrect**, **always incorrect**, **slower than serial**, **faster than serial**, or **none of the above**. Assume the default number of threads is greater than 1. Assume no thread will complete before another thread starts executing. Assume `arr` is an `int[]` of length `n`.

(a)
```
// Set element i of arr to i
#pragma omp parallel for
{
    for (int i = 0; i < n; i++)
        arr[i] = i;
}
```

(b)
```
// Set arr to be an array of Fibonacci numbers.
arr[0] = 0;
arr[1] = 1;
#pragma omp parallel for
for (int i = 2; i < n; i++)
    arr[i] = arr[i-1] + arr[i - 2];
```

(c)
```
// Set all elements in arr to 0;
int i;
#pragma omp parallel for
for (i = 0; i < n; i++)
    arr[i] = 0;
```

1.2 What potential issue can arise from this code?

```
1 // Decrements element i of arr. n is a multiple of omp_get_num_threads()
2 #pragma omp parallel
3 {
4 int threadCount = omp_get_num_threads();
5 int myThread = omp_get_thread_num();
6 for (int i = 0; i < n; i++) {
7     if (i % threadCount == myThread) arr[i] *= arr[i];
8     }
9 }
```

1.3
```
// Assume n holds the length of arr
double fast_product(double *arr, int n) {
    double product = 1;
    #pragma omp parallel for
    for (i = 0; i < n; i++) {
        product *= arr[n];
    }
    return product;
}
```

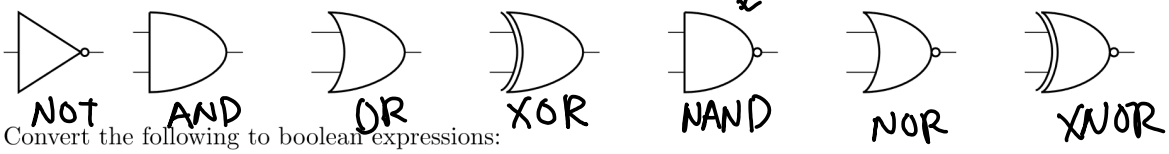
(a) What is wrong with this code?

(b) Fix the code using `#pragma omp critical`

(c) Fix the code using `#pragma omp reduction(operation: var)`.

2 Logic Gates

2.1 Label the following logic gates:



2.2 Convert the following to boolean expressions:

(a) NAND $A\bar{B} + \bar{A}B + \bar{A}\bar{B}$

(b) XOR $\bar{A}B + A\bar{B}$

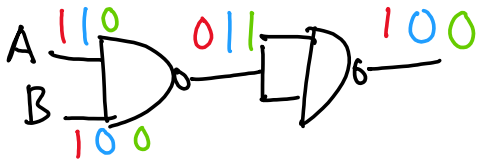
(c) XNOR $\bar{A}\bar{B} + AB$

NOT : $\bar{A}$

AND : $A \cdot B$

OR : $A + B$

2.3 Create an AND gate using only NAND gates.



1 1	1
1 0	0
0 1	0
0 0	0

2.4 How many different two-input logic gates can there be? How many n-input logic gates?