Assignment 1

Please read the document, ***General Requirements for Non-Programming Assignments***, posted on the course website and make sure you follow them when you do this assignment. The first two problems are really just math review exercises related to the topic of the course. If you have trouble with them, then review what you learned in your algebra and discrete structures classes.

1 Questions

1. (20%) The speed of a particular CPU is increased by a constant factor every day (like the principal in a bank account.) Suppose that every five years it is 12 times faster (e.g., if at the start of 2016, it is N Mflops, then at the start of 2021, it is $12N$ Mflops) . How long does it take for the speed to double? Express the answer as a fractional number of years to two decimal places.

2. (20%) The shortest distance that a message travels in a d-dimensional hypercube is 1 link; the longest distance is d links. If all possible source/destination pairs are equally likely, is the average distance a message needs to travel smaller or larger than $(1 + d)/2$? Prove your answer rigorously.

3. (20%) Prove that if node u is distance i from node v in a hypercube, then there are $i!$ different paths of length i from u to v (though some hypercube edges may appear in more than one path.)

4. (20%) Suppose that a particular computer can solve an instance of problem **B** whose size is 1,000,000 (in whatever units size is measured) in exactly 12 hours. Assume that the execution time does not depend on anything other than the speed of the CPU. In other words, the memory speed, size of memory, I/O bandwidth, and so on, do not affect the time to solve the problem. How large an instance of problem **B** can be solved in 12 hours by a computer whose CPU is 100 times faster if the program's running time $T(n)$ for a problem of size n is given by the following expressions:

   (a) $T(n) = n$
   (b) $T(n) = n \log_2 n$
   (c) $T(n) = n^2$
   (d) $T(n) = n^3$

   Again, think this through carefully. (The function in (b) does not have exact inverse, by the way, which is a hint of sorts.)

5. (20%) Assume that a butterfly network of order k connects $n = 2^k$ processors. Each processor is connected to an output switch in rank 0 and to an input switch in rank k. In other words, the switch in column j and rank 0 gets its *input message* from processor j and the switch in column j and rank k delivers its message to processor j. Messages only travel in one direction in a butterfly – towards switches of increasing rank. Write the implementation of a C function

   ```
   void route (const int k, const int i, const int j);
   ```

   that prints the route that a message from processor i to processor j takes in such a butterfly network of order k. The route must be written as a sequence of switches identified as pairs *(rank, col)*. For example, the output might look like this in a butterfly of order 2:

   ```
   (0,1); (1,3); (2 2)
   ```

The following main program will be used to call your function, and therefore your implementation must be in the file `hwk1.c`:

```
1 #include <stdio.h>
2 #include "hwk1.c"
3
4 int main()
5 {
6     int i,j,k;
7
8     printf("Enter order, source, and destination:");
9     scanf("%d %d %d", &k, &i, &j);
10    route(k,i,j);
11    return 0;
12 }
```

Your function must be correct code, not pseudocode, and must conform to the rules given in ***Programming Requirements and Guidelines*** on the course website.

2 Grading Rubric

There are four questions in this assignment, each worth the percentage indicated. Questions are assessed on their completeness and correctness and graded in accordance with the ***General Requirements for Non-Programming Assignments*** document posted on the course website.

3 Submitting the Homework

This assignment is due by the end of the day (i.e. 11:59PM, EST) on September 22, 2019. Follow these instructions precisely to submit it.

1. Put your name in the upper left corner of page 1.
2. You must type your solutions to problems 1 through 4, ***one solution per page***, and submit them as a single PDF.
3. The solution to problem 5 must be typed and be a syntactically correct C source code file. Therefore, your solution consists of two files. You should name the source code file `hwk1.c` and the other document `hwk1_theory.pdf`. The two files should be placed into a directory named `hwk1_username`, which should be used to create a single zip file of whatever name you choose. You must use the command

   ```
   zip -r hwk1_username hwk1_username
   ```

   which will create `hwk1_username.zip`. Assuming the zip file is so named, run the command

   ```
   /data/biocs/b/student.accounts/cs493.65/bin/submithwk_cs49365 -z 1 hwk1_username.zip
   ```

   where `hwk1_username.zip` is the name of your zip file in the current working directory and `1` is the number of the assignment. The `-z` is a switch that tells the program it is a zip file. This program will make a copy of your zip file and place it in the directory

   ```
   /data/biocs/b/student.accounts/cs493.65/hwks/hwk1/
   ```

   transferring ownership to me and setting permissions so that no one can read or modify it. ***You can only run these commands on a cslab host. You cannot run them on eniac, so remember to ssh into a cslab host before doing this!***