KING SAUD UNIVERSITY
COLLEGE OF COMPUTER & INFORMATION SCIENCES
DEPARTMENT OF COMPUTER SCIENCE

Course: Algorithms Design and Analysis - CSC311
Semester: Second Semester 2019/2020
Instructors: Dr. Mohamed Maher Ben Ismail & Dr. Fahad A Al-Dhelaan

Theoretical and Empirical Analysis of Algorithms

DEADLINE: ***April 16th 2019, 23:59****.*

1. Introduction

Three projects are briefly described below. You are expected to select one of these topics for your project. However, in exceptional circumstances we are willing to consider other proposals that you may have on your own, provided they have a very strong relation to the contents of the course. You can discuss the basic architecture of your system, such as main data structures, main components of the algorithm, design of the user interface for input/output, etc. with me so as to get started on the right track.

2. Project Topics:

a) BST/Hashing and Heap: Huffman coding and decoding:

Huffman Encoding is one of the simplest algorithms to compress data. Even though it is very old and simple , it is still widely used (eg : in few stages of JPEG, MPEG etc). In this project you will implement Huffman encoding and decoding. You can read up in Wikipedia or any other tutorial. *CLRS* has a simple explanation of Huffman coding in chapter 16.3.

You will implement compression and decompression of files using Huffman coding. Your program must take command line arguments such that it obeys the following interface:

To compress:

```
hc -c input_file
```

This will generate a *binary* file called `input_file.hc`

To decompress:

```
hc -d input_file.hc
```

which will generate a *binary* decompressed file called input_file.

For simplicity, your **alphabet** will be all the byte-values that appear in the uncompressed file.

To compress a file, your program must:

I. Read each byte in the file and count the frequency of each byte value.
II. Use a heap and construct the Huffman-tree, which is a **full binary tree.**
III. Either use a bst, hash, or the Huffman-tree itself to have a way of mapping bytes to encoded representation.
IV. In order to be able to decompress the file later, you will need the Huffman tree used to encode it. So, you must store a header for input_file.hc and **write** the Huffman_tree into the file. The format of input_file.hc will be described below.
V. Rewind to the beginning of the file.
VI. Go over each byte, encode it, and write the bits into the file. Please be careful with this step and make sure you convert a stream of bits into bytes in the correct way.

To decompress a file, your program must:

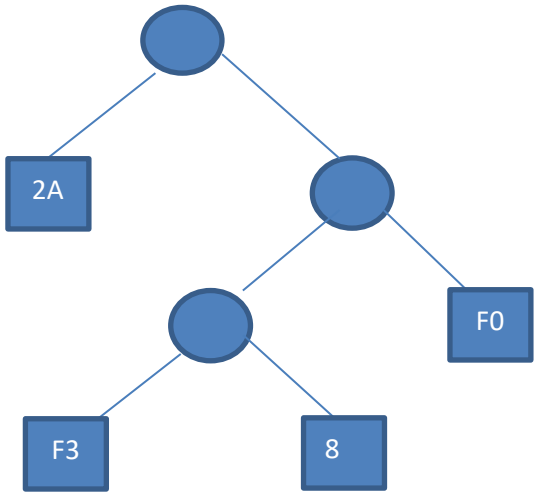
I. Read the first 12 bytes of input_file.hc to know the size of the file, the Huffman_tree and the encoded data.
II. Read the Huffman_tree's representation from the binary file and reconstruct it.
III. Read the encoded data, moving down along the Huffman-tree according to the bit values to repeatedly extract the original bytes.
IV. Write each extracted byte to *input_file* , the decompressed file.

Compressed file format:

Please adhere to the following file format. The file will be a *binary* file. It will have three parts:

I. The header: Bytes 0 to 3 (four bytes) will store the size of the file in bytes. Bytes 4 to 7 (4 bytes) will store the size of the tree in bytes. Bytes 8 to 11 (4 bytes) will store the size of the compressed data in bytes.

II. Huffman_tree: This will store a representation of the Huffman tree. Since the Huffman tree is a **full binary tree** (not necessarily complete), we can store it by using its preorder traversal. Each node can be represented by two bytes. The first byte is either zero or one. If the first byte is a zero, this node is internal and the second byte is not used (write it as zero). If the first byte is one, the node is a leaf node and the second byte will store the byte value this node corresponds to. Preorder traversal of a full binary tree allows you to write and read a binary tree easily. For example, suppose we have the tree:



Then, the Huffman tree will be represented inside the file as:

First byte	Second byte
0	0
1	2A
0	0
0	0
1	F3
1	8
1	F0

Make sure that the way you read and write the tree are **consistent.**

ii. The compressed data. This part of the fill will store the original file in its compressed form. If the total number of bits is not a multiple of 8, pad the last byte with zeros in the least significant bits.

For your empirical analysis of this project, plot either decompression or compression (or both) as a function of time for input files of varying sizes and formats.

b) Red-Black Trees: Shared Memory de-duplication:

Red black trees are one of the most important data structures used extensively in the Linux Kernel. For eg, recent kernels use Completely Fair Scheduler for process scheduling which depends on Red Black trees!

In this project, you will use Red black trees to simulate another of their popular applications- Shared memory de-dupulication. You can read up the algorithm used at https://developer.ibm.com/technologies/systems/tutorials/l-kernel-shared-memory/

Your system must have the following operations:

- ✓ Load: This will accept a list of <page id, hash of page content> records.
- ✓ Update: This will accept another list of <page id , hash of page content>. If page id already loaded, then just update its hash. This is equivalent to page content changing. If page id is not yet loaded, then add it to the system.
- ✓ De-dupulicate: In this operation, you must run the de-duplication algorithm explained in the website and display if any memory is freed.

c) Minimum Spanning Tree: Solving TSP for Metric Graphs using MST Heuristic:

Given an arbitrary metric graph, construct its Minimum spanning tree using Kruskal's algorithm. You can assume adjacency matrix representation of graphs. If you wish, you can reuse external libraries for heaps. Now use the constructed MST to find an approximate estimate for the TSP problem. You can choose to implement any of the two approximation algorithms specified in Wikipedia's entry on TSP – One with approximation factor of 1.5 (Christofides) or 2. Compare it with the optimal answer. You can use some external library to find the optimal solution to the TSP problem.

3. Experiments

Experiments have to be carried out according to the following directions.

1. Each algorithm has to be run on test data. Data will be generated in a random way.

2. If necessary, an algorithm may be run on test data a fixed number of times so that the running times obtained are meaningful

4. Running times will be plotted against input size.

4. Programming

Implementation of algorithms may be done in any language of student's choice. However, the language and its compiler should support certain features in order to be able to run the experiments properly. The choice of C, C++, Java, Maple, Matlab or the like should be enough. Source code has to be handed over.

5. Project Demonstration

Once the project is completed, the following is expected from you:

a) A demonstration of your project in which you show the various features of your system such as its correctness, efficiency, etc. You should be prepared to answer detailed questions on the system design and implementation during this demo. We will also examine your code to check for code quality, code documentation, etc.

b) You should also hand in a completed project report which contains details about your project, such as main data structures, main components of the algorithm, design of the user-interface for input/output, experimental results, e.g. charts of running time versus input size, etc.

c) You should also turn in your code and associated documentation (e.g. README files) so that everything can be backed up for future reference.

d) Email your code and all associated files with "CSC311-Project <Lastname>" as subject.

6. Written Report

A report describing the following points must be handed over.

• Brief explanation of the algorithms.

• Brief explanation of the implementations. It can be done by including sufficiently detailed comments in the code.
• Brief description of the experiment.
• Interpretation of experimental data. Comparison of experimental data with theoretical complexities.
• Conclusions. In this section students must draw his own conclusions (be creative).

The paper has to be written in correct English; it also has to possess clarity of thought.
Show me what you know; do not force to search for it through a poorly written paper.

7. Grading

We will take points off when:
• There is spelling mistakes
• It is plenty of irrelevant material. Down with the irrelevant!
• It lacks clarity of thought.
• It is lengthy, long-winded or poor in content.
• Code is not properly commented.
• Code is not properly structured.
• Variables have absurd names.
• There are run-time errors.

8. Questions and Office Hours

Mr. Rami, Dr. Fahad and Dr. Maher are willing to answer your questions about algorithms, complexity or the experiment. They will not answer questions about coding errors as it is our feeling that, at this point, writing error-free code is your responsibility.