COMP20290
Algorithms

Assignment 1

Huffman Compression

Objective

In this assignment, you will build your own utility for compressing text - one you could practically use to compress your own files. Your task for this programming assignment will be to implement a fully functional Huffman coding suite equipped with methods to both compress and decompress text files.

Huffman encoding is an example of a lossless compression algorithm that works particularly well on text but can, in fact, be applied to any type of file. Using Huffman encoding to compress a file can reduce the storage it requires by a third, half, or even more, in some situations.

Huffman's algorithm is an example of a **Greedy algorithm**. It's called greedy because the two smallest nodes are chosen at each step, and this local decision results in a globally optimal encoding tree. In general, greedy algorithms use small-grained, or local minimal/maximal choices to result in a global minimum/maximum.

If you encounter any difficulties with this, make sure to consult the lectures, this excellent Wikipedia article or this detailed overview.

Tasks

1. Task 1: Develop a Huffman tree by hand (15%)
2. Task 2: Code a fully-functional Huffman algorithm (50%)
3. Task 3: Test and analyze your Huffman algorithm with various inputs (35%)

What is provided?

Some helper classes are provided so you can focus on building your Huffman algorithm. In addition, various input data is provided to allow you to test your code. You are welcome to add to this.

Deliverables:

A completed assignment should consist of:

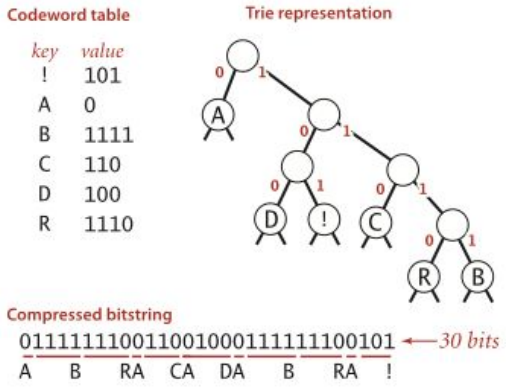
1. a hand-drawn Huffman tree with a codeword table for the given phrase (as pdf)
2. a fully functional Huffman algorithm that can compress and decompress input files
3. a 1 page analysis of your analysis of your algorithm's performance (as pdf)

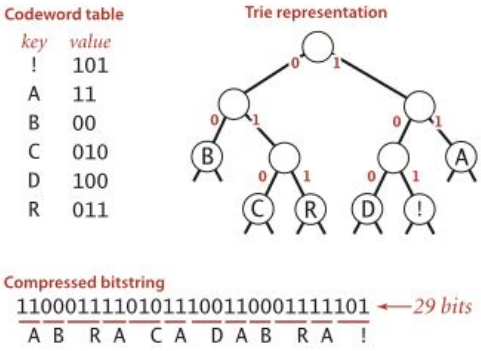
Submission

Submissions are due by 5pm on May 3rd. All of the deliverables should be submitted via GitHub Classroom.

****this assignment can be completed on your own or in groups of 2 or 3. If you are completing this as a group, each person needs to submit the assignment separately with a cover sheet (e.g., pdf) that includes the names and student numbers of the people on the project. This will be taken into consideration when grading your submission.**

Task 1 Code Huffman Tree of phrase by hand





Create a Huffman tree and codeword table for the phrase: “There is no place like home”.

You should follow the steps outlined in the lectures to create your Huffman tree by hand which include:

1. Count the characters in the input phrase (including the space character)
2. Build your tree from the bottom up beginning with the two characters with the lowest frequency
3. Merge these into a node / sub-trie with combined weight
4. Continue working through your character frequency table until you reach the root node
5. Encode each character (using either 0 or 1 for left forks in the tree etc.)
6. Write out your codeword table

In summary, the basic idea is that you take the two nodes with the lowest frequency and combine them with an internal-parent-node. The new parent-node takes the combined frequencies of its two sub-children as its frequency and is put back with all of the other nodes. This process is repeated until there is only one node left, which is the root-node. You then create the codes for each character by tracing a path from root to leaf node (aggregating the bits along the way).

Submission: Upload a photo of your hand-drawn character frequency table, your Huffman tree and the resulting codeword table as part of the submission

Joan Mora Grau Std number: 19202899

Task 1

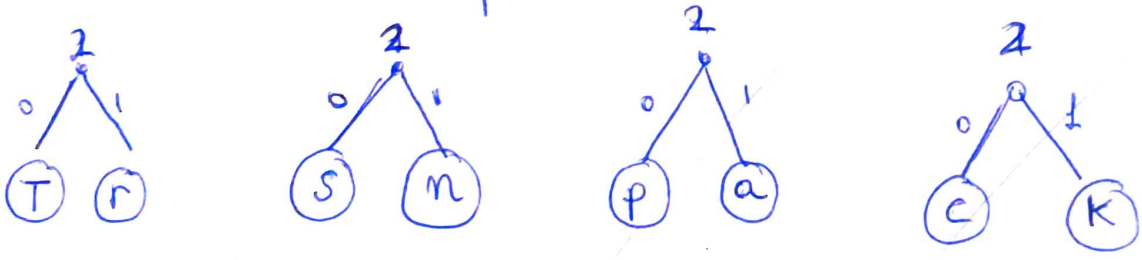
"There is no place like home"

1- Frequency table

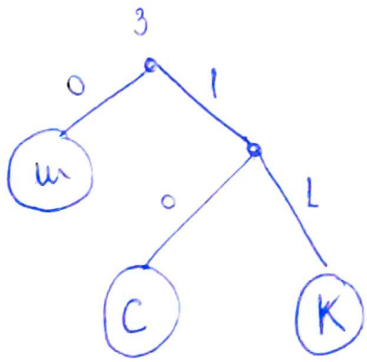
T	h	e	r	i	s	n	o	p	l	a	c	k	m	space
1	2	5	1	2	1	1	2	1	2	1	1	1	1	5

2- Build the tree → we will build suboptimal trees until we reach the optimal solution → greedy strategy.

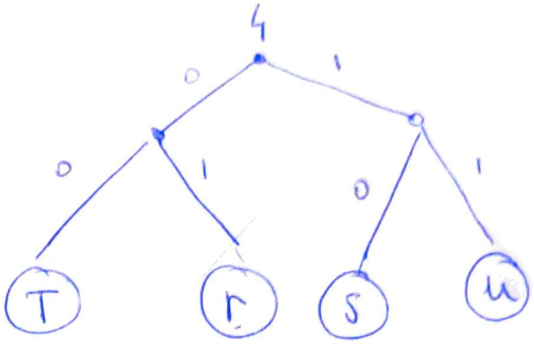
* trees that add up 2:



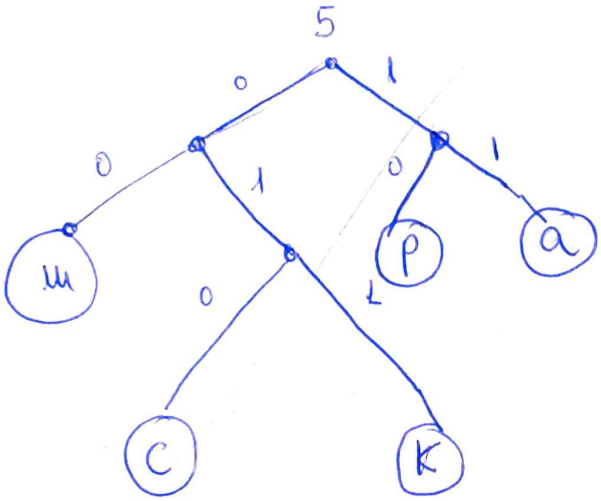
* nodes that sum up 3:



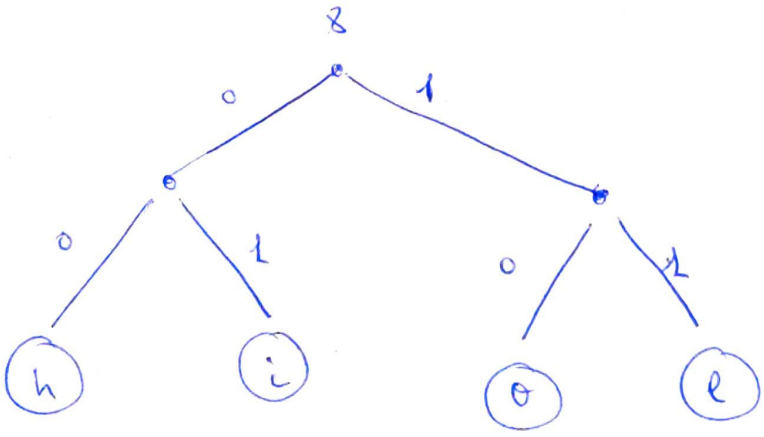
* subtrees weighted 4



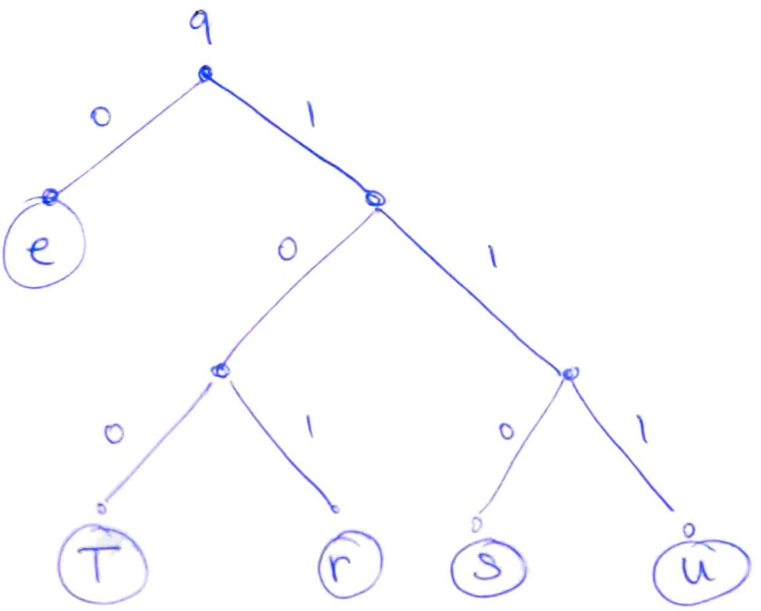
* Subtrees weighted 5:



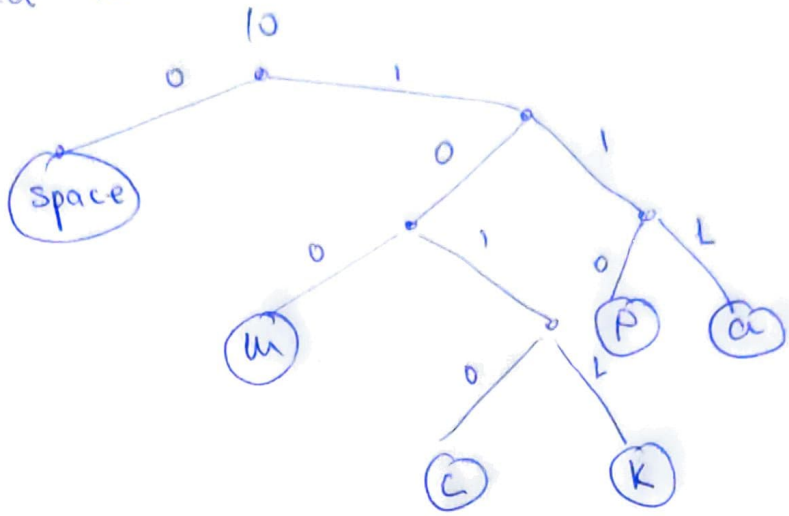
(*) subtrees weighted 8



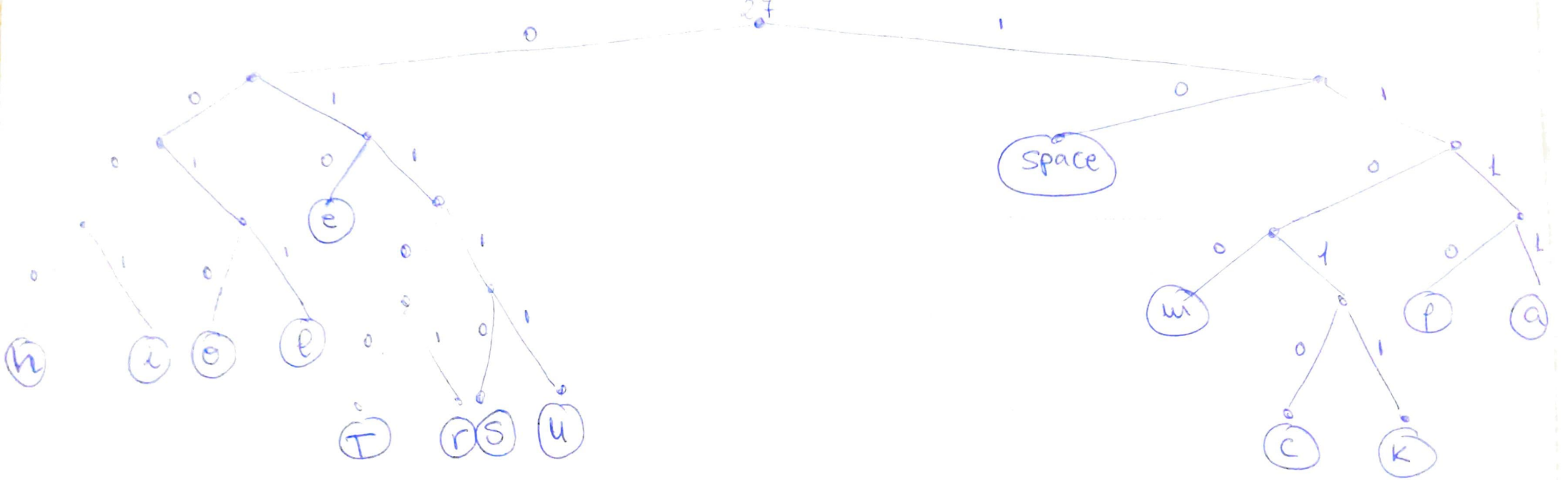
⊗ Subtree weighted 9:



Subtree weighted 10:



We combine first the subtrees weighted 8-9 and then the result to the one weighted 10. The final solution would be:



CodeWord table

h = 0000
i = 0001
o = 0010
l = 0011
e = 010
T = 01100
r = 01101
S = 01110
u = 01111
Space = 10
w = 1100
c = 11010
k = 11011
f = 1110
a = 1111

Task 2: Build your Huffman Compression Suite

For Task 2, you are tasked with building a fully functional Huffman compression algorithm that can compress and decompress input files. Your program should enable a user to compress and decompress files using the standard Huffman algorithm for encoding and decoding.

To complete this task you need to:

1. Create a class called HuffmanAlgorithm which can read in and output files
2. Implement a compress method which will involve:
    a. Building an encoding trie
    b. Writing the trie (as a bitstream) for use in decompression
    c. Use the trie to encode the input byte-stream as a bitstream
3. Implement a decompress method which involve:
    a. Reading in the encoding trie (the one created in the compression stage)
    b. Using this trie then to decompress the bitstream

Compression

The steps you'll take to perform a Huffman encoding of a given text source file into a destination compressed file are:

1. **Read in the input:** you can use the binary input stream helper function.

2**. Count character frequencies**: examine the input file to count the number of occurrences of each character and store them in a data structure (e.g., a map).

3. **Build the Huffman encoding tree**: Build a binary tree where each node represents a character and its count of occurrences in the file. Follow the same process you used for Task 1 to join nodes together. Remember the same text can be encoded in different ways. A **priority** queue can be used to help build the tree along the way.

4. **Build the corresponding codeword table:** Traverse the trie to identify the binary encodings for each character.

5. **Write the trie:** Output the trie you created encoded as a bitstring (Alternatively **w**rite the character count: Write out the count of input characters also encoded as a bitstring)

6. Apply Huffman coding: Re-examine each character in the input and output the encoded binary version of that character to the destination file.

Decompression

Decompressing a file that has been compressed with your Huffman algorithm is a little bit more straightforward and is somewhat the reverse of the compression steps.
You will need to:

1. Read in the input
2. Read the trie that is encoded at the beginning of the bitstream
3. Use this trie to decode the bitstream
4. Output the decompressed characters
5. Use the trie to decode the bitstream

Your finished algorithm should be able to be called from the command line with additional arguments that tell your function whether to compress or decompress, what input file to use for compress and what output file to use to write to e..g., 'java HuffmanCompression compress filename output filename'

Deliverable: Push your Huffman algorithm to GitHub classroom

Task 3: Compression Analysis

Your final task is to test the performance of your Huffman algorithm, benchmark its performance against other algorithms and answer the analysis questions below.

Step 1. Compress the provided text files
Calculate the time to compress and compression ratios for each of the provided files (**and one file of your choosing)**. Include the results in a summary table and upload the resulting compressed files as part of your submission. You can use the tools provided to calculate the compression ratios and time taken to compress them.

Q1. Calculate the compression ratio achieved for each file. Also, report the time to compress and decompress each file.

Time (ms)	Input File	Output File	Original Size (bits)	Compressed size (bits)	Compression Ratio
6	medTale.txt	medTaleCompressed.txt	45056	23912	53.07%
5	genomeVirus.txt	genomeVirusCompressed	50008	12576	25.15%
103	mobydick.txt	mobyDickCompressed	9531704	5341208	56.04%
1	q32x48.bin	q32x48Compressed	1536	816	53.13%
39	Pride_And_Prejudice-Jane_Austen.txt	pride_and_prejudiceCompressed	1832216	1036904	56.59%

Step 2. Decompress the files you compressed
Q2. Take the files you have just compressed and decompress them. Report the final bits of the decompressed files and the time taken to decompress each file.

Time (ms)	Input File	Output File	Bits
1	q32x48Compressed	q32x48Decompressed	1536
64	mobyDickCompressed	mobyDickDecompressed	9531704
6	medTaleCompressed	medTaleDecompressed	45056
3	genomeVirusCompressed	genomeVirusDecompressed	50008
27	pride_and_prejudiceCompressed	prejudiceDecompressed	1832216

Step 3. Analysis of your results
Assess the results of the above.

Q3. What happens if you try to compress one of the already compressed files? Why do you think this occurs?

We compressed the Pride and Prejudice file from an already compressed file and achieve a compressed radio of 98.9%.

Q4. Use the provided RunLength function to compress the bitmap file q32x48.bin. Do the same with your Huffman algorithm. Compare your results. What reason can you give for the difference in compression rates?

Run Length Encoding: Compression_ratio = 74.48 %

Huffman: Compression_Ratio = 53.13 %

We achieve a 20 % more compression with Huffman compression.

Deliverables: A 1-page analysis of your compression / decompression experiments. This can be included as a pdf at the root of your submitted repo or as part of a ReadMe file.

Helper files

The following helper functions have been provided as part of the assignment repo as well as some starter code for your Huffman utility. You do **NOT HAVE TO USE THIS CODE** and are free to choose your own implementations, including different data structures, if you like.

BinaryStdIn - Reads bits from the system

BinaryStdOut - Writes bits to the system

BinaryDump - Allows you to examine the contents of byte-streams and bitstreams while you're testing

HexDump - same as BinaryDump but in more compact Hex form

RunLength - an implementation of RunLength encoding that you can use in Task 3 to benchmark your Huffman algorithm. You can call it from the command line with: **java RunLength - < yourfilename** to compress your chosen file and **java RunLength + < yourfilename** to decompress it.

Helper Data

Several text files have been provided in the github assignment folder that are commonly used to test the effectiveness of compression algorithms. Use them to assess the performance of your implementation of Huffman and benchmark against that of other compression algorithms.

mobydick.txt - Full text of MobyDick

medTale.txt - several sample paragraphs

q32x48.bin - a bitmap

genomeVirus.txt - genetic code