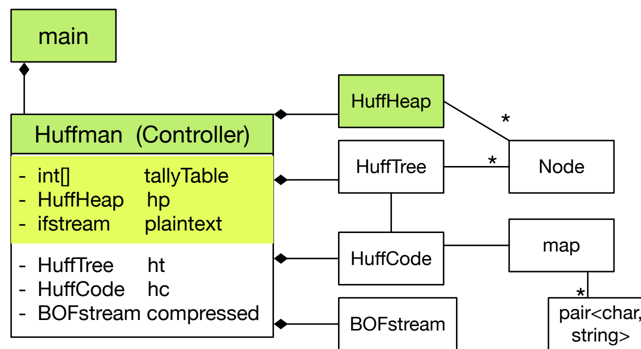
CSCI 6620 Data Structures – Fall 2018

Program 5: Phases 1 and 2 of Huffman Compression: Heap and Node

1 Huffman Codes: Due October 16, 2018

A Huffman code can be used to compress a file. It replaces fixed-size, one-byte characters by variable-length codes (strings of bits). The codes for the most frequently used characters will be shorter than 8 bits, those for unusual characters will be longer. No codes are generated for characters that are not used. The input file is read twice, once to generate the code, then again to encode the file. This is an effective compression method for all ASCII text files, because the ASCII code uses only 7 bits and the Huffman Code uses all 8 bits in a byte.

Coding this multi-step algorithm will be your work for the next month. In the process, you will use several major data structures and produce a bit-oriented output file. The UML diagram below shows the overall architecture of the completed project. The green and yellow parts will be created in Program 5.



2 Goals of Program 5

1. To use a command-line argument for main(), the name of the file to be compressed.
2. To write the first two phases of a file compression program that we be further developed in programs 6 and 7.
3. To use characters as subscripts for an array.
4. To implement / adapt the heap algorithms.

2.1 The main Program

The main program. In main():

1. Call banner()
2. Then pick up the name of the input file from the command line. Call the Huffman constructor with this file name as its parameter.
3. Call Huffman::compress().
4. Call bye() and end execution.

2.2 P5 Phase 1: The Initial Tally

In this phase, you will count the number of times each character appears in a text file. Debug this before you start Phase 2.

Huffman, the Controller Class. Declare a class named `Huffman`. It will be instantiated by main and will, in turn, instantiate and run all other parts of the application. Data members for P5 are:

1. `tally`, an array of 256 integers for counting occurrences of the 256 possible ASCII characters.
2. An ifstream for the input file.
3. A counter for the number of input characters

Function members for this phase include:

1. A constructor with one string parameter. Open and verify the file named by the parameter.
2. A print function that prints the final contents of the tally array and the number of characters in the file. This function is for debugging. It is not part of the compression algorithm. Code will be added to this function in later assignments.
3. A private worker function named `doTally()`.
   (a) Read the input file one character at a time, in a way that does not skip whitespace.
   (b) Use the character code to subscript the tally array, and add 1 to the appropriate array slot.
   (c) When eof is found, make your input file so that it is ready to read again by seeking to 0 bytes from the beginning of the file: `streamName.seekg (0, is.beg);`
4. A public worker function named `compress`. This is the primary function that implements the application. It will be called from main and it calls all other major functions. At this time implement the following:
   (a) Call `doTally()`. When it returns, print the results of the tally, including the number of characters in the input file.
   (b) Call the Heap constructor with a pointer to the tally array as its parameter.
   (c) Call `heapify()`; it must return a Node* (alias Tree) that is the root of a HuffTree.
   (d) When `heapify()` returns, call `Heap::print()`.
   (e) Calls on other phases of the program will be added here, as the project develops.

Sample data. Below is a text that will be used to illustrate all phases of this process. Please note that this IS NOT the required input file to be used for submission of your project.

Morals rule everything! (Or is it money?)

The non-zero results of tallying our text are shown below in ASCII sequence order:

!	(	)	?	' '	M	O	a	e	g	h	i	l	m	n	o	r	s	t	u	v	y
1	1	1	1	6	1	1	1	4	1	1	3	2	1	2	2	4	2	2	1	1	2

3 P5, Phase 2: The HuffHeap

3.1 The Node Class

This is a helper class for both the HuffHeap class and the HuffTree class. It has four data members. Two (a frequency and a character) will be used by the Heap class. The other two are Node pointers. All four data members will be used by the Tree class.

Because this class will be used by two other classes, define it as a fully separate private class that gives friendship to HuffHeap (and later also to HuffTree). At the top of the Node class, write a typedef that makes the name `Tree` a synonym for Node*

1. Define a private Node constructor with two parameters, the character and its frequency. Use the parameters to initialize two data members. Set the other two to nullptr. In P6, you will define another constructor with different parameters.
2. Define a private print function that prints the char first, followed by a space, followed by the frequency. If a char is invisible, print the ascii code instead.
3. Other functions may be added in P6.

3.2 The HuffHeap Class

The Heap class will make a min-heap out of the tallies created in Phase 1.

Data members.

1. An empty array of 257 Trees. 256 is the maximum possible number of tallies, and slot 0 of this array will always be left empty.
2. An integer subscript of the last array slot that is in use. This is also the number of tally objects in the array. Set this initially to 0. The first Node should go in slot 1.
3. Integers for use by the heap algorithms: the subscripts of father, leftSon, and rightSon.

Public function members.

1. A public constructor with one parameter, the int[] tally array. This will be called from the Huffman class. Use the parameter to access the array in the Huffman class. Walk through the array, looking for non-zero counters. If you find one, construct a new Node and store the pointer in the next open slot in the Heap array. The result for our text will be:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	!	(	)	?	' '	M	O	a	e	g	h	i	l	m	n	o	r	s	t	u	v	y
0	1	1	1	1	6	1	1	1	4	1	1	3	2	1	2	2	4	2	2	1	1	2

Figure 1: The heap array before heapify().

2. A public print function. Output the number of Trees in the heap and then print all of them (use delegation).
3. A public worker function named `heapify()` or `buildHeap()`. Implement the buildHeap algorithm from the notes. In the process, implement private functions for `upHheap()` and `downHheap()`. Note; the rest of the Heap functions will be added in Program 6.

   Now look at Figure 1. This array is not in heap order. For example, the path from the root to the node at subscript 21 goes through nodes 1, 2, 5, 10, and 21. This path is not sorted because node 5 has a higher frequency than node 10. To make this into a legal min-heap, we execute the $heapify()$ operation. Refer to the separate Heapify handout for detailed descriptions of the functions and a trace of the heapify algorithm.