

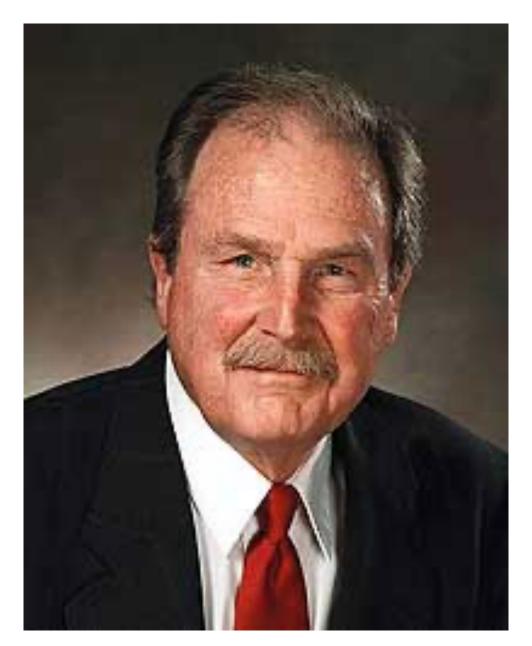


John Backus

Turing Award 1977

- Inventor of first high-level programming language FORTRAN
- Co-Inventor of Backus-Naur Form (BNF), a notation for describing syntax structure.

Huffman Coding



CSCI 1102 Computer Science 2

"ALABAMA"

'A' is run of the mill, 'B', 'L', & 'M' are more *interesting*, i.e., contain more Information than 'A'.

Instead of an 8-bit fixedlength code for a letter, choose a variable-length code reflecting the amount of information in the letter.

"ALABAMA"

 $A_4 L_1 B_1 M_1$

A Frequency Table

B₁ L₁ M₁ A₄

Low frequency => High Priority, head of the queue! (letters arrived in alphabetical order) High frequency
⇒ Low Priority,
back of the queue!

$B_1 L_1 M_1 A_4$

Algorithm step: while the priority queue has more than one entry, remove two entries, combine them and reinsert the result back into the priority queue.

$B_1 L_1 M_1 A_4$

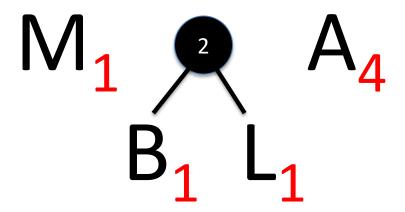
 B_1 L_1 M_1 A_4

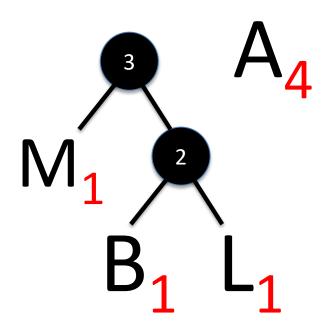


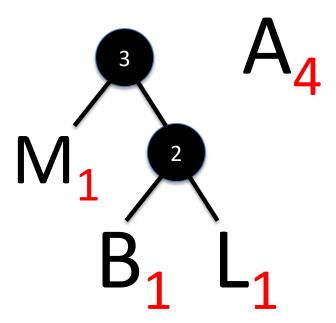
The items in the priority queue are weighted trees.

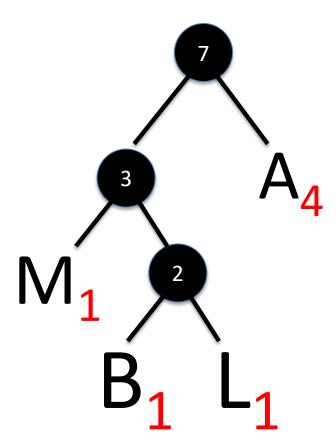
$$B_1 L_1 M_1 A_4$$

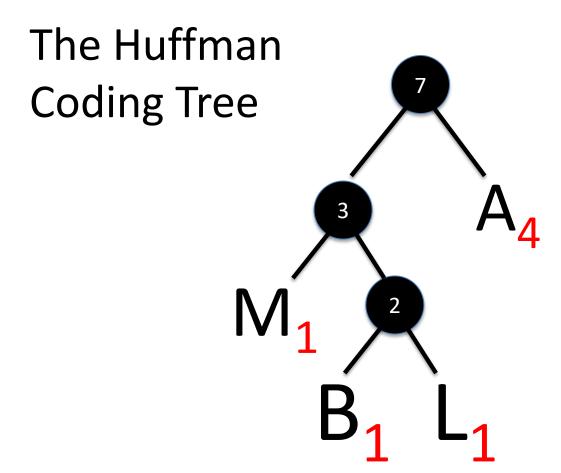
The items in the priority queue are weighted trees.

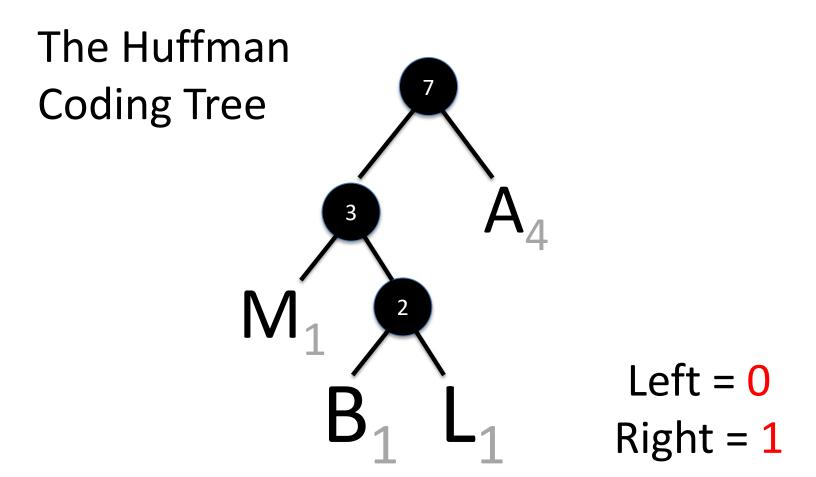


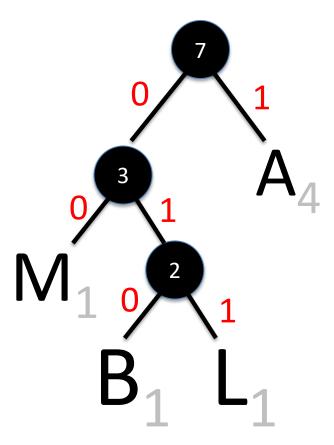












$$M = 00$$
, $B = 010$; $L = 011$; $A = 1$

A L A B A M A 1 011 1 010 1

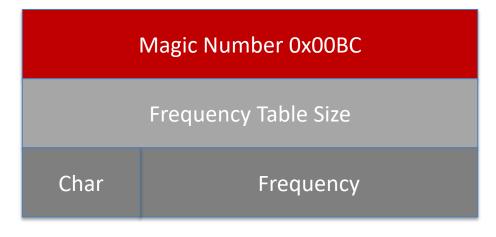
$$M = 00$$
, $B = 010$; $L = 011$; $A = 1$

ALABAMA 101110101001

12 bits << 56 bits

$$M = 00$$
, $B = 010$; $L = 011$; $A = 1$

The .zip File



• • •

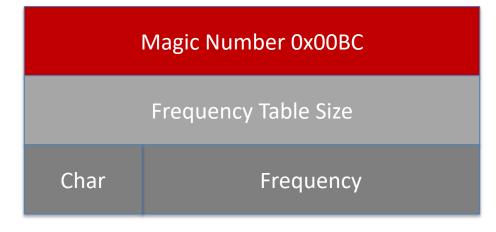
Char	Frequency
Bit String	

BinaryIn/BinaryOut

read/write Short

read/write Int

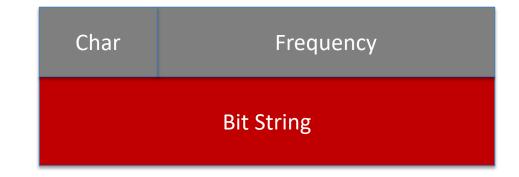
read/write Byte



read/write Int

• • •

readInt(int r)



Unix hexdump of lincoln.zip

```
0000000
                  00
                      00
                          00
                               23
                                  0a
                                      00
                                           00
                                               00
                                                   19
                                                       20
              C0
          2c
              00
                  00
                      00
                           18
                               2d
                                   00
                                       00
                                           00
                                               01
                                                   2e
                                                       00
                                                                       42
                      01
0000020
          00
                  00
                          46
                               00
                                   00
                                       00
                                           01
                                                   00
              00
                                                       00
                                                                       00
0000030
          00
              00
                  03
                      4e
                          00
                               00
                                   00
                                       01
                                           54
                                               00
                                                   00
                                      62
                          00
                               00
0000040
          00
                      00
                                   66
                                           00
                                               00
                                                   00
                                                       0d
                                                                       00
0000050
                  00
                      00
                          00
                               3a
                                   65
                                       00
                                           00
                                               00
                                                       66
                          1b
                               68
0000060
                  00
                      00
                                   00
                                       00
                                           00
                                               50
                                                   69
                                                                       6h
0000070
          00
              00
                  00
                      03
                          6c
                               00
                                   00
                                       00
                                           2a
                                               6d
                                                                       00
0000080
          00
              00
                          00
                               00
                                   00
                                       5d
                                               00
                                                   00
                                                       00
                                                                       00
0000090
          00
                      00
                          00
                               00
                                       73
                                           00
                                               00
                                                   00
                                                                       00
00000a0
                  00
                      00
                          00
                               15
                                   76
                                           00
                                               00
                                      5a
                                   52
                                           78
                                                       fh
          79
              00
                  00
                      00
                          0a
                                                                       19
```

magic number 0x0bc0

```
0000000
                   00
                       00
                           00
                               23
                                       00
                                            00
                                                00
                                                    19
                                                        20
               C<sub>0</sub>
                                   0a
                               2d
          2c
               00
                   00
                       00
                           18
                                   00
                                        00
                                            00
                                                01
                                                    2e
                                                        00
                       01
0000020
          00
                   00
                           46
                               00
                                   00
                                        00
                                            01
                                                    00
                                                        00
                                                                         00
           00
               00
                   03
                           00
                               00
                                   00
                                        01
                                                00
                                                    00
                       4e
                                       62
                               00
0000040
           00
                       00
                           00
                                   66
                                            00
                                                00
                                                    00
                                                        0d
                                                                         00
0000050
                   00
                       00
                           00
                               3a
                                        00
                                            00
                                                00
                                                        66
                               68
0000060
                           1b
                   00
                       00
                                   00
                                        00
                                            00
                                                50
                                                    69
                                                                         6h
0000070
           00
               00
                   00
                       03
                           6c
                               00
                                   00
                                        00
                                            2a
                                                6d
                                                                         00
0000080
           00
               00
                           00
                               00
                                   00
                                        5d
                                                00
                                                    00
                                                                         00
0000090
          00
                       00
                           00
                               00
                                        73
                                            00
                                                00
                                                    00
                                                                         00
00000a0
                   00
                       00
                           00
                               15
                                    76
                                            00
                                                00
                                       5a
                                   52
                                                        fb
                                            78
           79
                   00
                       00
                           0a
                                                                         19
```

Frequency table size $0x23 = 35_{10}$

```
0000000
                  00
                      00
                          00
                              23
                                  0a
                                      00
                                          00
                                              00
                                                   19
                                                       20
              C0
                          18
          2c
              00
                  00
                      00
                              2d
                                  00
                                      00
                                          00
                                              01
                                                  2e
                                                      00
                                                                       42
                      01
                          46
0000020
          00
                  00
                              00
                                  00
                                      00
                                          01
                                                   00
                                                       00
                                                                       00
                                          54
          00
              00
                  03
                          00
                              00
                                  00
                                      01
                                              00
                                                  00
                                                      00
                      4e
                                      62
          00
                                  66
0000040
                  61
                      00
                          00
                              00
                                          00
                                              00
                                                  00
                                                       0d
                                                                       00
0000050
                  00
                      00
                          00
                              3a
                                  65
                                      00
                                          00
                                              00
                                                  a5
                                                       66
                              68
                                      00
0000060
                  00
                      00
                          1b
                                  00
                                          00
                                              50
                                                  69
                                                                       6h
                                          2a
0000070
          00
              00
                  00
                      03
                          6C
                              00
                                  00
                                      00
                                              6d
                                                   00
                                                                       00
0000080
          00
              00
                          00
                              00
                                  00
                                      5d
                                              00
                                                   00
                                                       00
                                                                       00
                                  4f
0000090
          00
                      00
                          00
                              00
                                      73
                                          00
                                              00
                                                  00
                                                                       00
                                  76
00000a0
                  00
                      00
                          00
                              15
                                      00
                                          00
                                              00
                                      5a
                                  52
                                          78
                                              92
                                                       fh
          79
              00
                  00
                      00
                          0a
                                                                       19
```

Table entry: 0x0a = newline, $0x19 = 25_{10}$

```
0000000
              C0
                  00
                      00
                          00
                              23
                                      00
                                          00
                                              00
                                                       20
                                  0a
          2c
              00
                  00
                      00
                          18
                              2d
                                  00
                                      00
                                          00
                                              01
                                                  2e
                                                      00
                                                                      42
                  00
0000020
          00
                      01
                          46
                              00
                                  00
                                      00
                                          01
                                                   00
              00
                                                                       00
          00
              00
                          00
                              00
                                  00
                                      01
                                          54
                                              00
                                                  00
                      4e
                  61
                              00
                                      62
0000040
          00
                      00
                          00
                                  66
                                          00
                                              00
                                                  00
                                                       0d
                                                                       00
0000050
                  00
                      00
                          00
                              3a
                                  65
                                      00
                                          00
                                              00
                                                       66
                          1b
                              68
0000060
                  00
                      00
                                  00
                                      00
                                          00
                                              50
                                                  69
                                                                      6h
0000070
          00
              00
                  00
                      03
                          6c
                              00
                                  00
                                      00
                                          2a
                                              6d
                                                                      00
                                      5d
0000080
          00
              00
                          00
                              00
                                  00
                                              00
                                                   00
                                                       00
                                                                       00
0000090
          00
                      00
                          00
                              00
                                  4f
                                      73
                                          00
                                              00
                                                  00
                                                                       00
00000a0
                  00
                      00
                          00
                              15
                                  76
                                      00
                                          00
                                              00
                                      5a
                                  52
                                          78
          79
                  00
                      00
                          0a
                                                       fh
                                                                       19
```

Frequency Table

```
0000000
              C0
                   00
                      00
                           00
                               23
                                   0a
                                       00
                                           00
                                               00
                           18
                               2d
0000010
              00
                   00
                       00
                                   00
                                       00
                                           00
                                               01
                                                       00
                                                                       42
0000020
          00
                           46
                               00
                                                   00
                                                       00
                   00
                                   00
                                       00
                                           01
                                                                       00
0000030
          00
                           00
                               00
                                   00
                                                   00
                       4e
0000040
          00
                                       62
                       00
                           00
                               00
                                   66
                                           00
                                               00
                                                                       00
                                                       0 d
0000050
                   00
                       00
                           00
                               3a
                                       00
                                           00
                                               00
                                                       66
                               68
0000060
                   00
                       00
                           1b
                                   00
                                       00
                                           00
                                               50
                                                   69
                                                                       6b
0000070
          00
                       03
                               00
                                   00
                                               6d
                                                                       00
0000080
          00
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0000090
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                                                   00
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00000a0
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                           00
                               15
                                           00
                                               00
                                       5a
                                               92
                                                       fb
                           0a
                                   52
                                           78
00000b0
                       00
                                                                       19
```

Start of Bit Stream

```
0000000
                  00
                       00
                           00
                               23
                                           00
               C0
                                   0a
                                       00
                                               00
                                                   19
                                                       20
              00
                   00
                       00
                           18
                               2d
                                   00
                                       00
                                           00
                                               01
                                                       00
                                                                        42
                       01
                                           01
0000020
          00
                   00
                           46
                               00
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               00
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                                       01
                                               00
                       4e
                                       62
0000040
          00
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                               00
                                   66
                                           00
                                               00
                                                   00
                                                       0d
                                                                        00
0000050
                   00
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                           00
                               3a
                                       00
                                           00
                                               00
                                                       66
                           1b
                               68
0000060
                   00
                       00
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                                       00
                                           00
                                               50
                                                   69
                                                                        6h
0000070
          00
                   00
                       03
                               00
                                   00
                                       00
                                               6d
                                                                        00
                                       5d
0000080
          00
                           00
                               00
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                                               00
                                                   00
                                                                        00
               00
0000090
          00
                       00
                           00
                               00
                                       73
                                           00
                                               00
                                                   00
                                                                        00
00000a0
                       00
                           00
                               15
                                   76
                                           00
                                               00
                                       5a
           79
                   00
                       00
                           0a
                                   52
                                           78
                                                                        19
```