VL07 Data Transformations

17. January

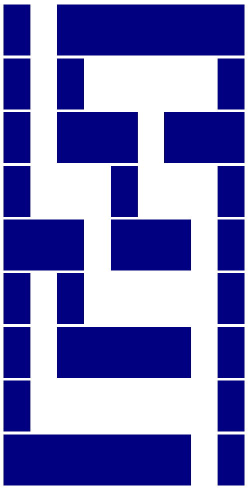
Agenda

- Maze Solver
- Sorting: Reprise
- Run-Length Encoding
- LZW Compression
- Huffman Encoding

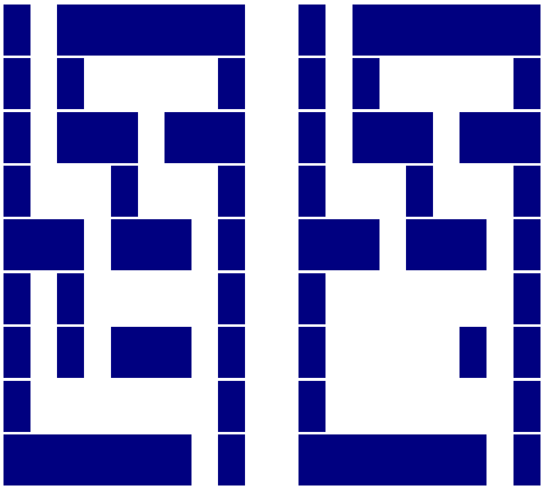
Maze Solver

1. Data consistency check
2. Lookup entry and exit
3. Recursive walk-through
4. Print result

Example input



Models for Further Consideration



Sorting: Reprise

Know-how

- Compare and swap
- Empty array and single-element array are sorted
- Idempotence

Specific Algorithms

- Array merging
- Priority queue/binary heap
    - Recursive phase
    - Linear phase

Run-Length Encoding (RLE)

Run-length encoding is a form of lossless data compression in which runs of data (sequences in which the same data value occurs in many consecutive data elements) are stored as a single data value and count, rather than as the original run.

Example RLE-friendly input

- Example input: AAAAAAAAAABBBBB
- Example output: 10A5B

Example RLE-unfriendly input

- Example input: ABCABCABC
- Example output: 1A1B1C1A1B1C1A1B1C

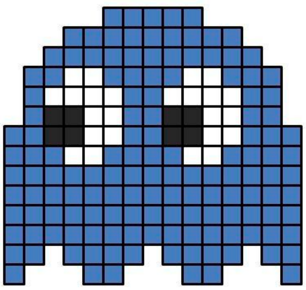


Figure 1. A graphical example of input data that compresses efficiently with RLE

Exercise 0: Write a RLE compressor and de-compressor.

LZW Compression

The Lempel-Ziv-Welch algorithm provides loss-less data compression. It was published by Welch in 1984 as an improved implementation of the original LZ78 algorithm published by Lempel and Ziv in 1978. The algorithm entered the public domain in 2004.

Compression

```
Dictionary<string, int> our_dictionary =
new Dictionary<string, int>();

/* prepare initial dictionary */
for(int i = 0 ; i < 256; i++)
our_dictionary.Add(((char)i).ToString(),
i);

string w = "";  /* empty string */
while (char c =
get_next_uncompressed_character())
{
    if (our_dictionary.ContainsKey(w + c))
    {
        w = w + c;
    }
    else
    {
        output(our_dictionary[w]);

        our_dictionary.Add(w + c,
our_dictionary.Count);
        w = c;
```

```
    }
}

if(w != "")
    output(our_dictionary[w]);
```

Example input: abcabcabc

Extra dictionary entries	Output
ab ⇒ 256	97,
bc ⇒ 257	98,
ca ⇒ 258	99,
abc ⇒ 259	256,
cab ⇒ 260	258,
bc ⇒ 261	257,

LZW compress

abcabcabc

w	c	w+c	output	dict
""	a	a		
a	b	ab	97	ab ⇒ 256
b	c	bc	98	bc ⇒ 257
c	a	ca	99	ca ⇒ 258
a	b	ab		
ab	c	abc	256	abc ⇒ 259
c	a	ca		
ca	b	cab	258	cab ⇒ 260
b	c	bc		
bc			257	

output: 97, 98, 99, 256, 258, 257

remarks: 1st code is always ascii (<256)

Decompression

```
Dictionary<int, string> our_dictionary =
new Dictionary<int, string>();

/* prepare initial dictionary */
for(int i = 0 ; i < 256; i++)
our_dictionary.Add(i,
((char)i).ToString());

string w =
((char)get_next_compressed_int()).ToString();
string result = w;

while (int c = get_next_compressed_int())
{
    string entry;

    if (our_dictionary.ContainsKey(c)) {
        entry = our_dictionary(c);
    } else {
        throw new Exception("Badly
compressed data!");
    }

    result = result + entry;


our_dictionary.Add(our_dictionary.Count, w
+ entry.SubString(0,1));

    w = entry;
}
```

```
output($result);
```

LZW decompress

97, 98, 99, 256, 258, 257

w	result	c	entry	dict
a	a	98	b	
	ab			256 => ab
b	abc	99	c	257 => bc
c		256	ab	258 => ca
ab	abcab	258	ca	259 => abc
ca	abcabca	257	bc	260 => cab
	abcabcabc			

Huffman Encoding

Huffman encoding is a way to assign binary codes to used symbols (characters). Its aim is to map each character to its shortest binary representation in scope of the complete input. Symbols that are used often get shorter binary representation, less often symbols are encoded with longer code.

Table 1. Example input = "mississippi"

Occurence	Character	Binary Code
2x	*p*	101
4x	*s*	0
1x	*m*	100
4x	*i*	11

Result: **100110011001110110111** (that is 21 bits vs. 88 bits but don't forget you need to define the dictionary)

The Huffman coding scheme takes each symbol and its frequency of occurrence, and generates proper encoding for each symbol **taking account of the weights of each symbol**, so that higher weighted symbols have fewer bits in their encodings.

The algorithm:

1. Create a leaf node for each symbol and add it to the priority queue (see `java.util.PriorityQueue`, heap sort)
2. While there is more than one node in the queue:

- Get two nodes by removing the node with the lowest probability twice
- Create a new internal node with these two nodes as children and with probability equal to the sum of the two nodes' probabilities
- Put the new node back to the queue

3. There’s a single node in the queue

Paths in the constructed binary tree from root to leaves make the resulting code. Accumulate 0 for each transition to the left and 1 for transitions to the right side.

Table 2. Example input "abcd"

Occurence	Character	Binary Code
1x	*a*	00
1x	*b*	01
1x	*c*	10
1x	*d*	11

Huffman Encoding

input: abcd

---

a^1, b^1, c^1, d^1 ← get occurences

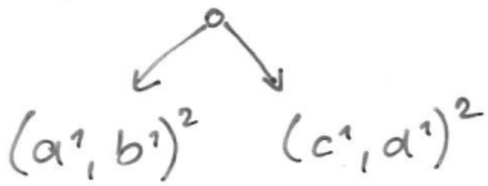
$(a^1, b^1)^2, c^1, d^1$

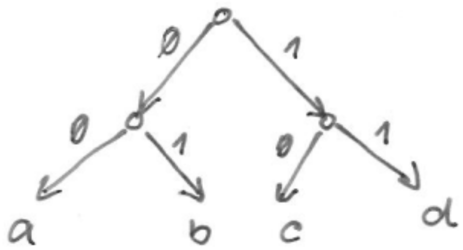
$(a^1, b^1)^2, (c^1, d^1)^2$

$((a^1, b^1)^2, (c^1, d^1)^2)^4$ ← single element, stop

- take 2 with smallest occ.
- combine them
- repeat

now 'unfold' the tree





- mark each transition 0/1

a	00
b	01
c	10
d	11

- read in top-down direction

Table 3. Example input "aaabcd"

Occurence	Character	Binary Code
3x	*a*	0
1x	*b*	11
1x	*c*	100
1x	*d*	101

Huffman Encoding

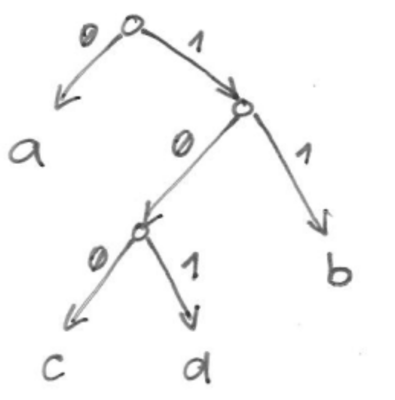
input: aaabcd

a^3, b^1, c^1, d^1

$a^3, (c^1, d^1)^2, b^1$

$a^3, ((c^1, d^1)^2, b^1)^3$

$(a^3, ((c^1, d^1)^2, b^1)^3)^6$



a	0
b	11
c	100
d	101