## Example

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| s0 | y | a | i | r | w | i | s | e | m | a | n |
| s1 | a | i | r | w | i | s | e | m | a | n | y |
| s2 | i | r | w | i | s | e | m | a | n | y | a |
| s3 | r | w | i | s | e | m | a | n | y | a | i |
| s4 | w | i | s | e | m | a | n | y | a | i | r |
| s5 | i | s | e | m | a | n | y | a | i | r | w |
| s6 | s | e | m | a | n | y | a | i | r | w | i |
| s7 | e | m | a | n | y | a | i | r | w | i | s |
| s8 | m | a | n | y | a | i | r | w | i | s | e |
| s9 | a | n | y | a | i | r | w | i | s | e | m |
| s10 | n | y | a | i | r | w | i | s | e | m | a |


© Klein S. T. and Wiseman Y.

## Burrows Wheeler Transform

- Difficult problems can often be simplified by performing a transformation on a data set.
- The Burrows-Wheeler Transform, or BWT, transforms a block of data into a format that is extremely well suited for compression.
- The BWT is an algorithm that takes a block of data and rearranges it using a sorting algorithm.
- The transformation is reversible, meaning the original ordering of the data elements can be restored with no loss of fidelity.


© Klein S. T. and Wiseman Y.

## How to decode

| L | F | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| y | a | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| m | a | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| s | e | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| a | i | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| w | i | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| e | m | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| a | n | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| i | r | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| i | s | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| r | w | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| n | y | ? | ? | ? | ? | ? | ? | ? | ? | ? |


© Klein S. T. and Wiseman Y.

## Example (cont.)

| | F | | | | | | | | | L |
|---|---|---|---|---|---|---|---|---|---|---|
| s1 | a | i | r | w | i | s | e | m | a | n | y |
| s9 | a | n | y | a | i | r | w | i | s | e | m |
| s7 | e | m | a | n | y | a | i | r | w | i | s |
| s2 | i | r | w | i | s | e | m | a | n | y | a |
| s5 | i | s | e | m | a | n | y | a | i | r | w |
| s8 | m | a | n | y | a | i | r | w | i | s | e |
| s10 | n | y | a | i | r | w | i | s | e | m | a |
| s3 | r | w | i | s | e | m | a | n | y | a | i |
| s6 | s | e | m | a | n | y | a | i | r | w | i |
| s4 | w | i | s | e | m | a | n | y | a | i | r |
| s0 | y | a | i | r | w | i | s | e | m | a | n |


© Klein S. T. and Wiseman Y.

## Move to Front

- A Move to Front encoder keeps all 256 possible codes in a list.
- Each time a character is to be output, the encoder:
  - sends its position in the list.
  - moves it to the front.
- g g g g l g g l g f g g g g g g g g f will be 103,0,0,0,108,1,0,1,1,104,1,0,0,0,0,0,0,0,1 (ASCII codes of f,g,l are 102,103,108 respectively)


© Klein S. T. and Wiseman Y.

## Snippet of a sorted data

- g ood and evil, thou shalt not eat of it: for in th
- g ood and evil. And a river went out of Eden to wat
- g ood and evil. And when the woman saw that the tre
- g ood and evil: and now, lest he put forth his hand
- l ood crieth unto me from the ground. And now art t
- g ood for food, and that it was pleasant to the eye
- g ood for food; the tree of life also in the midst
- l ood from thy hand; When thou tillest the ground,
- g ood that the man should be alone; I will make him
- f ood, and that it was pleasant to the eyes, and a
- g ood. And God blessed them, saying, Be fruitful, a
- g ood. And God said, Let the earth bring forth gras
- g ood. And God said, Let us make man in our image,
- g ood. And the evening and the morning were the fou
- g ood. And the evening and the morning were the six
- g ood. And the evening and the morning were the thi
- g ood: and God divided the light from the darkness.
- g ood: there is bdellium and the onyx stone. And th
- f ood; the tree of life also in the midst of the ga


© Klein S. T. and Wiseman Y.

## Disadvantages

- The BWT is performed on an entire block of data at once.
  - Most of today's familiar lossless compression algorithms operate in streaming mode, reading a single byte or a few bytes at a time. But with this new transform, we want to operate on the largest chunks of data possible.
  - Sometimes, the file must be split up and processed a block at a time.
- The sorting operations needed by BWT will have O(nlogn) performance, meaning bigger blocks might slow things down considerably.

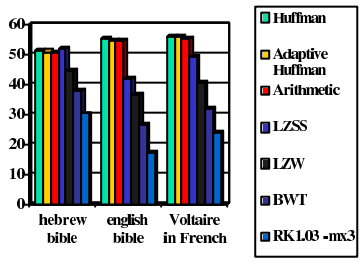

© Klein S. T. and Wiseman Y.

## Final Step

- If the output of the BWT operation contains a high proportion of repeated characters, we can expect that applying the Move To Front encoder will give us a file:
  - filled with lots of zeros
  - heavily weighted towards the lowest integers.
- At that point, the file can finally be compressed using an entropy encoder, typically a Huffman or arithmetic encoder.


© Klein S. T. and Wiseman Y.

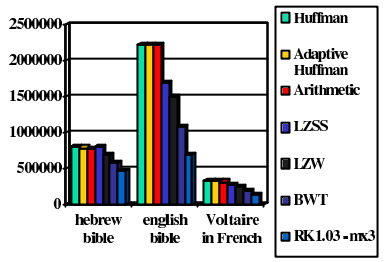
## Comparison in percents





© Klein S. T. and Wiseman Y.

## Comparison of methods





© Klein S. T. and Wiseman Y.