Data Reduction Techniques

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Structure

1. Introduction
2. Scientists and their methods
3. Computer scientists and their methods
   - Compression
   - Comparison of algorithms
     - Fast compression algorithms
     - Algorithms with good ratio
   - Deduplication
   - Recomputing
4. Conclusion

Motivation

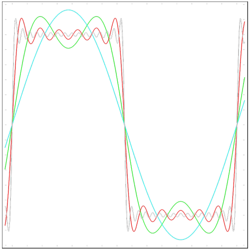
- gap between computational speed and storage speed is widening
- in HPC storage systems in two-digit PB and throughput around TB/s
- growing difficulties handling I/O reducible by compression
- little or no support by file system, especially parallel
- usually needs constant power supply
- transmitting data costs time and energy (e.g.Keppler satellite)
- data intense research (e.g. square kilometre array (SKA) some PB/s)

Different Approaches To Data Reduction

- Scientists vs computer scientists
- Which data is really necessary?
- Which precision is needed?
- How can I compress the data as small and fast as possible?

Data Reduction

- rounding
- Fourier series (periodic phenomena)/ Fourier transform (aperiodic p.): transforming data and only analysing until certain precision



$$f(t) = \frac{a_0}{2} + \sum_{k=1}^{\infty}(a_k \cdot cos(kt) + b_k \cdot sin(kt))$$

- statistical methods like linear regression and smoothing

Compression

- compression speed = uncompressed size/Δ time; in $[\frac{MB}{s}]$
- compression ratio = uncompressed size/compressed size, e.g. $\frac{12MB}{3MB} = 4$
- space savings = 1 - (compressed size/uncompressed size), e.g. $1 - \frac{3}{12} = 0.75$
- lossy vs lossless compression
- system level (e.g. part of file system) vs user level

Detecting incompressible data

- Komolgorov complexity
  - shortest description of statements that will produce the character sequence looked at
  - data: ABABABABABABABABABAB
  - shortest description: AB*10
  - measurement for structuredness of data and compressibility
- prefix estimation
- entropy: $H = \sum_{i=1}^{m} p_i log_2 p_i$ (Huffman-Encoding)
- heuristics, e.g. IBM solution

Detecting incompressible data

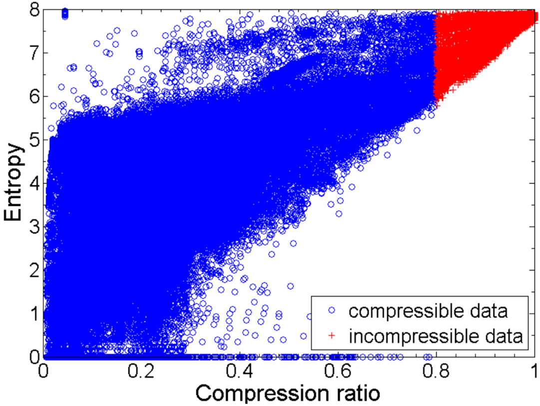


Abbildung: Entropy - compressibility relation [HKM+13, p. 8]

(here compression ratio: compressed size/uncompressed size)
(0.8≙1.25)

Detecting incompressible data

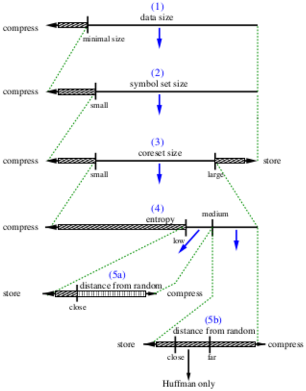


Abbildung: IBM heuristics to detect incompressible data

[HKM+13, p. 9]

Comparison of different compression algorithms

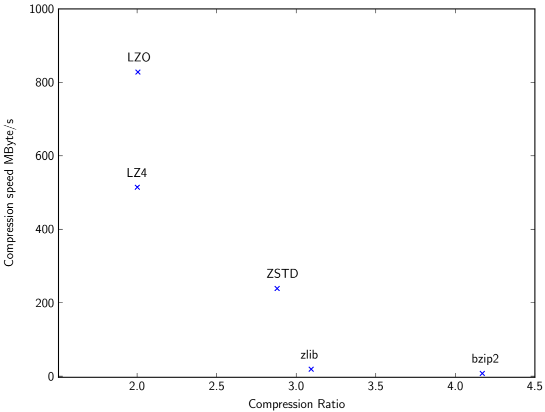


Abbildung: Results PRE-project by Hans Ole Hatzel

Fast compression algorithms

- LZ-family (LZ77,LZ78, LZSS, LZMA, LZRW, LZO, LZJB, LZ4)
- dictionary or search buffer and sliding window

Buffer						sliding w.				(x,y,z)
1	2	3	4	5	6	1	2	3	4	(-,-,-)
						B	A	N	A	(0,0,B)
					B	A	N	A	N	(0,0,A)
				B	A	N	A	N	E	(0,0,N)
			B	A	N	A	N	E		(5,2,E)
B	A	N	A	N	E					(-,-,-)

- LZO = Lempel-Ziv-Oberhumer (1996)
- LZ4: author: Yann Collet(2011), default in OpenZFS
- LZ4 Fast: different way of updating hash table

Why LZO and LZ4 are so much faster

- "Be warned:
  the main source code in the 'src' directory is a real pain to understand as I've experimented with hundreds of slightly different versions.
  It contains many #if and some gotos, and is *completely optimized for speed* and not for readability." - Markus Franz Xaver Oberhumer
- do not search all possible matches for best solution, missing some short matches
- no entropy encoding, no analysis of symbol frequency
- byte output not bit output
- optimisation for modern CPUs
- possibly using heuristics to detect incompressible data

Deflate format

- RFC 1950(ZLIB),1951(DEFLATE),1952(GZIP)
- deflate = LZSS + Huffman Encoding; not patented itself
- ZIP: Phil Katz; patented implementations (.zip)
- GZIP: Jean-Loup Gailly, Mark Adler; (.gz /.tgz)
- ZLIB: Jean-Loup Gailly, Mark Adler; originally intended for libpng

GZIP-Level

- RFC 1950: "FLEVEL (Compression level) These flags are available for use by specific compression methods. The 'deflate' method (CM = 8) sets these flags as follows:
  0 - compressor used fastest algorithm
  1 - compressor used fast algorithm
  2 - compressor used default algorithm
  3 - compressor used maximum compression, slowest algorithm"
- ZLIB manual:" Compression levels.
  #define Z_NO_COMPRESSION 0
  #define Z_BEST_SPEED 1
  #define Z_BEST_COMPRESSION 9
  #define Z_DEFAULT_COMPRESSION (-1) "
- -1 is equivalent to level 6 best compromise

Zopfli and Gipfeli and Brotli

author: Jyrki Alakuijala

“Gipfeli is a Swiss name for croissant. We chose this name, because croissants can be compressed well and quickly”

- implements deflate format
- slower than gzip (around x80-100)
- compression density is about 5% better

- based on LZ77 with fast entropy coding
- compression ratio is similar to Zlib in the fastest mode
- more than three times faster than Zlib

- new format
- increase of around 20% in compression density in contrast to deflate, speed stays the same
- pre-defined static dictionary of around 13.000 strings

Bzip2 and pbzip2

- author: Julian Seward
- Run-length encoding
- Borrows-Wheeler transform

rotation	sort	result
ANANAS$	$ANANAS	S
$ANANAS	ANANAS$	$
S$ANANA	ANAS$AN	N
AS$ANAN	AS$ANAN	N
NAS$ANA	NANAS$A	A
ANAS$AN	NAS$ANA	A
NANAS$A	S$ANANA	A

- Move to front coding
- Huffman encoding
- slow compression speed but one of the best compression ratios
- parallel version with nearly linear speed up

Blosc

- blocking, shuffling and compression library project
- improving speed between memory and CPU
- goal: be faster than memcpy()
- BloscLZ based on FASTLZ
- support for LZ4, LZ4HC, Zlib, Snappy

Deduplication

- data split in blocks
- block stored only once
- table needed to find right block
- a lot of memory needed to hold tables

Recomputing

- only suitable for data which is accessed rarely
- results are not saved
- recomputed when needed
- virtualisation provides necessary environment to recompute data on different system

Conclusion

- data reduction necessary to slow down gap widening between computational speed and storage speed
- mathematical operations to keep more important data and discard less valuable
- on system level fast algorithms to compress all the time
- user level: algorithms with very good compression ratio
- deduplication: difficult to handle
- recomputation: not ready yet

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