CO3096/7096
Compression Methods for Multimedia

Rajeev Raman

Logistics

- Module convenor: Prof Rajeev Raman
  - Room F33, x3894, r.raman@leicester.ac.uk
  - Open door policy.
- Plan:
  - 29 classroom lectures + 2 e-lectures + 18 problem class/ surgery
- BSc pre-requisites: CO1012.
  - Helpful: CO1016, CO2011, CO2016.
- General – basic maths, including binary numbers, simple probability calculations.

Assessment

- Exam 50%, continuous 50%.
  - Continuous
  - 3 “part unseen” class tests of equal weight.
  - Based upon worksheets 1-8.
  - 7096: we take best 2 of 3 class tests.
- Exam 2 hours.
  - will not test learning outcomes already tested in class tests.
  - 2 questions. 20% of Exam will be “challenging”.

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Planned Content of Meetings (Actual Content May Vary)

WB	Week #	TT Week	*Mon 0900*	*Mon 1000*	*Tue 1000*	*Thu 1400*	*Fri 1200*
15-Jan-17	14	26				**LEC (C1, Intro)**	**LEC (C1, Intro)**
22-Jan-17	15	27	**LEC (C1, Intro)**	**LEC (C2, Fund)**	**LEC (C2, Fund)**	***Sur; Logs, WS1***	***Sur; WS1, WS2***
29-Jan-17	16	28	**LEC (C2, Fund)**	**LEC (C2, Fund)**	**LEC (C3, MLS)**	***Sur; WS2, WS3***	***Sur; WS3***
05-Feb-17	17	29	**LEC (C3, MLS)**	**LEC (C3, MLS)**	**LEC (C3, MLS)**	***Sur; WS3***	**CLASS TEST 1**
12-Feb-17	18	30	**LEC (C4, RLE)**	**LEC (C4, Dictionary)**	**LEC (C4, Dictionary)**	***Sur; WS4***	***Sur; WS4***
19-Feb-17	19	31	**LEC (C5, BWT)**	**LEC (C5, BWT)**	**LEC (C5, BWT)**	***Sur; WS5***	***Sur; WS5***
26-Feb-17	20	32	**MATRIX REFRESHER**	**LEC (C7, Image)**	**LEC (C7, Image)**	***Sur; WS4****	**CLASS TEST 2**
05-Mar-17	21	33	**LEC (C7, Image)**	**LEC (C7, Image)**	**LEC (C7, Image)**	***Sur; WS6***	***Sur; WS7***
12-Mar-17	22	34	**LEC (C8, Video)**	**LEC (C8, Video)**	**LEC (C8, Video)**	**Sur; WS7**	***Sur; WS8***
19-Mar-17	23	35	**LEC (C8, Video)**	**Revision/overflow**	**Revision/overflow**	***Sur; WS4****	**CLASS TEST 3**
26-Mar-17	24	36	**Revision/overflow**	**Revision/overflow**	**Revision/overflow**		

There are two e-lectures. Both should be read before 5th March

Materials

- Course notes: photocopies at start of week 3 for anyone who wants them.
  - PDFs available.
- Course slides: will *NOT* be photocopied.
- Books:
  - Li and Drew: Recommended, not essential.
  - Hoffmann, Sayood, others: Reference.
- Other materials on website and online. E.g.
  - “Data compression explained”, online book by Matt Mahoney.

Aims of Course

- To study methods for compression of symbolic data as well as diffuse data.
- To gain an appreciation of the ubiquity and importance of compression technologies.

Data Compression

- What is it?
- Motivation for compression.
- History of compression.
- Compression concepts
- Terminology
- Modelling versus coding

What is it?

- Data compression means changing a *redundant* data representation to a *succinct* one, and recovering the original data from the succinct one (*de-compression*).
- Data compression means changing a *redundant* data representation to a *succinct* one, and recovering the original data from the succinct one (*de-compression*)

Is this compression?

- Data compression means changing a *redundant* data representation to a *succinct* one, and recovering the original data from the succinct one (de-compression).
- (x2)

Motivations for compression

Efficient use of storage

- Many storage media have fixed size:
  - CD-ROM: 650MB, DVDs: 8GB, BD: 50GB
  - b = bits, B = bytes, k/K ≈ x 10^3, M ≈ x 10^6, G ≈ x 10^9.
  - 10 min of raw HDTV video ~80GB.
- Portable devices have little memory:
  - Smartphones: 4GB RAM (+flash).
  - Smart cards: <128Kb.
- Memory can be expensive and raises power consumption.
- Cloud-based storage charge per GB/TB
  - Compression saves on data center costs.

Efficient Transmission

- Bandwidth is cheap! (Lay another fibre-optic cable.)
  - ‘Last mile’ problem: not economical to lay fibre-optic cables to individual subscribers so `last mile’ is still copper.
  - ADSL (20 Mbps, upload speed?).
    - Kbps = 1000 bits per second.
    - 56Kbps (GPRS), <5Mbps (3G, stationary customer – moving, lower).
- Pay per volume:
  - Network operator costs est. €1.50/GB [Nokia Siemens, 2 Orange mobile broadband 5p/MB to £6/MB (international roaming). 4G.
- Storage media data transfer rates:
  - “up to” 8MBps (48X CD-ROM), 22MBps (16X DVD), 40MBps (8x BD), 125MBps (7200rpm HDD).
  - Data rate for raw HDTV video ~ 200MBps.
- Compression essential for real-time transmission.

Related to Machine Learning

- Compression's foundations: *information theory.*
  - How much information there is in data.
  - How to describe data to computers (*algorithmic* information theory).
  - How much one piece of data helps you to understand another piece of data (*mutual* information).
- In machine learning:
  - "one piece" : training data.
  - "another piece" : test data.

Related to Machine Learning

- Links go deep (but the maths is beyond the scope of the module).
- Direct uses:
  - Use of compression algorithms for predicting sequences [Gueniche et al. PAKDD'15]
  - Use of "minimum description length" to choose between different explanations of the same data.
    - "Occam's razor"

A History of Compression

- 1st cent. BC—1930: Shorthand, Braille, Morse code, Analog compression.
- late ’40s ’50s: Information theory, Huffman codes.
- ’70s: Arithmetic coding, dictionary-based compression (Lempel-Ziv methods).
- early ’80s: FAX, Videoconferencing, still images (JPEG).
- late ’80s, early ’90s: Motion video compression (MPEG).
- ’90s: Disk compression, Satellite TV, Digital TV (HDTV), DVD, MP3, MP4.
- 00’s: Streaming video, portability, “convergence”, XML compression, working with compressed data, “compressed sensing”.
- 10’s: Mobile video, interactive video/games, working with compressed data.

Basic Notions

Keywords

- Compression = Coding.
- De-compression = De-coding.
- “Codec”
- “Redundancy”
- Raw data = uncompressed data.
- Compression ratio: size of raw data / size of compressed data = $x > 1$ (?).
  - Expressed as *x* : 1. (simple example slide about 2:1).
  - b = bits, B = bytes, k/K ≈ x 10^3, M ≈ x 10^6, G ≈ x 10^9, Mbps, GBps etc.

Lossless compression

- Reconstruct the original *exactly* from the compressed version.

Raw data *X*

↓

Compressed file

↓

Raw data *X*

- Applied to so-called *symbolic* data such as: character text, numeric data, computer source code and binaries and icons.
- Relatively low compression ratios (2:1 to 6:1).

Lossless essential when is essential

- When compressing text (or else meaning is lost or changed).

... pay Bob 5,000 quid ...

↓

Compressed file

↓

... pay Rob 5,000 quid ...

Lossless compression is essential

- When compressing source code or executables (otherwise program behaviour can change)

```
for(i = 0; i < 10; i++)
A[i] = 0;
```

↓

Compressed file

↓

```
for(i = 0; i < 10; j++)
A[i] = 0;
```

Lossless essential when

- Archiving medical images and images preserved or legal purposes (any alteration is unacceptable).
- http://www.theregister.co.uk/2013/08/06/xerox_copier_flaw_means_dodgy_numbers_and_dangerous_designs/

Lossy compression

- Reconstruct the original *approximately* from the compressed version.

Raw data *X*

↓

Compressed file

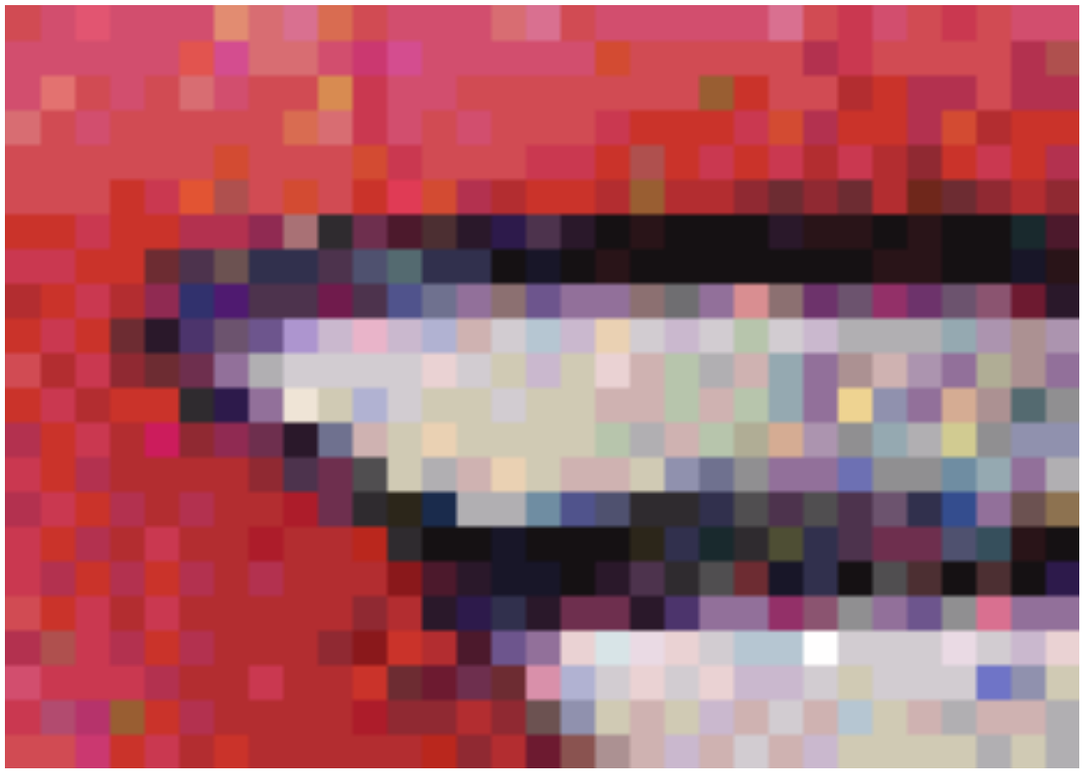
↓

Raw data *X'*

- *X* and *X'* are "similar" but not identical.

Lossy compression

Lossy compression



Lossy compression

- Trade-off compression vs. approximation.
- Approximation criteria
  - ‘Appears similar’ to humans.
  - Numerical criteria like ‘mean-squared error’ etc.
- Applied to diffuse data such as image, video and audio data.
- Ratios of 100:1 can be achieved while preserving a reasonable approximation.

Lossy compression

- Original 124KB; left 3.4KB; right 17.4KB.

Conclusion

- You have understood:
  - Compression/decompression
  - Compression ratio
  - Lossless/lossy