4C8: Digital Image and Video Processing

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Introduction

4c8 is an introduction to the digital signal processing algorithms that are at the core of image and video compression.

2D Signal Processing concepts such as 2D Convolution, 2D Z-Transforms and 2D Discrete Fourier Transforms.

Compression Standards for Images and Videos such as JPEG and MPEG2.

A note about Image/Video Processing and Deep Learning

Computer Vision and Image Processing and both been profoundly changed by Deep Learning, and pretty much anything you would like to do with images nowadays relies on Deep Neural Networks.

In 4C8, we will not look at Deep Learning, and only focus on image and video compression, which are, up to now, still underpinned with core signal processing concepts.

For anything else, eg. image analysis, manipulation, etc. (ie. 90% of image processing applications), you'll end up using Deep Learning, so please refer to 4C16/5C16!

`https://frcs.github.io/4C16-LectureNotes/`

A Note

Some of the course material has been built upon course material from Prof. **Anil Kokaram** and some from Assistant Prof. **David Corrigan**, who have been teaching 4c8 in previous years.

Course Structure

- Monday 9-10 [M17]
- Monday 13-14 [Crossland Theatre]
- Tuesday 9-10 [Synge, HAM] (not Synge)
- Tuesday 11-13 (Labs) [CADLAB]

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lectures: on Mondays 9-10, 13-14, Tuesdays 9-10

labs: on Tuesdays 11-13, **25% of the final mark**

exam: 2 hours

Lecture Material: `https://github.com/frcs/4C8-2223`

Prerequisites

Signal Processing prerequisites include:

- mainly 3c1 but 4c5 helps too
- Z-Transform
- Convolution
- Fourier Transform

Information Theory prerequisites include:

- Entropy, Entropy Rate, Shannon's Coding Theorem *etc*.
- Huffman Coding

but these will be covered again.

A Digital Picture

Anatomy of a picture:

resolution: 600 x 400 pixels

sRGB colour space

0	12	255

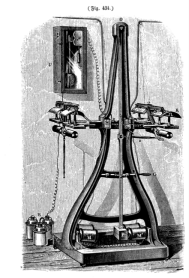
8bit per colour channel (0-255)

it could be floating point (0-1)

The Rise of Digital Media

1880-1920s	First Fax Machines (Wire/Wireless)
1950s	First Digital Images
1960s	Digital Image Processing Research takes off
1970s	Medical Imaging emerges (eg. CAT)
1973	DIP used for first time in the cinema (Westworld)
1980s	Introduction of Digital Video in Television Production
1990s	Introduction of Digital Video cameras and tape (DigiBeta and DV standard)
Late 90s	Digital Television and DVD emerges
2000s	Video on mobile phones / video over internet/ HDTV / 3DTV
Now	Online streaming of high quality Video (incl. 4k) (Netflix, Youtube etc.)

The Rise of Digital Media

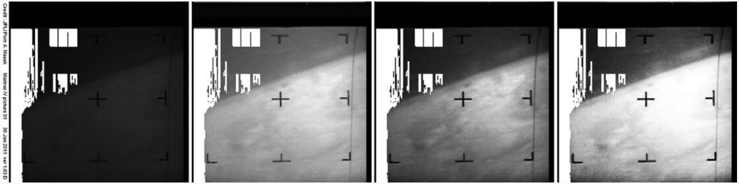


Late 1800s early 1900s: First Fax Machines (wired and wireless)

The Rise of Digital Media

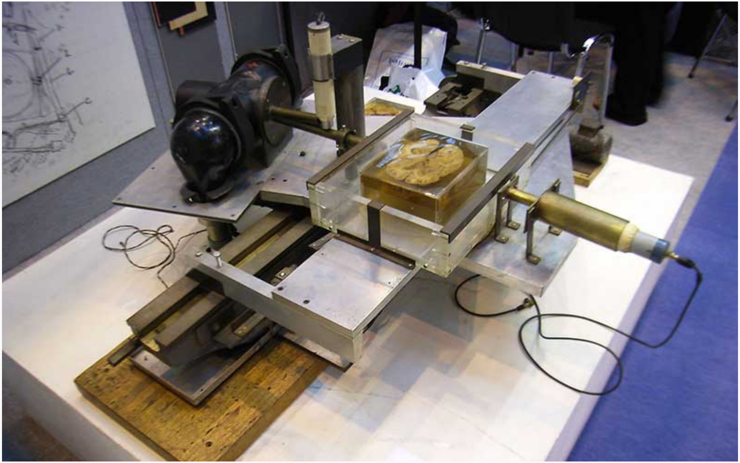
1957: First image to be digitally scanned and stored as digital pixels on the Standards Eastern Automatic Computer (SEAC).

The Rise of Digital Media



1964: The first digital image from Mars by Mariner 4 using a television camera, mounted on a scan platform.

The Rise of Digital Media



1972: First commercially available CT scanner.

The Rise of Digital Media

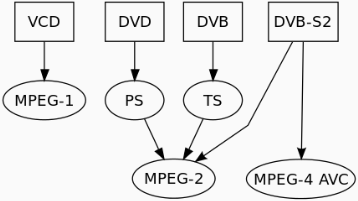
1973: Digital Image Processing used for first time in the cinema (Westworld).

The Rise of Digital Media

1980s: Introduction of Digital Video in Television Production

1990s: introduction of Digital Video Cameras and Tape (DigiBeta and DV standard)

The Rise of Digital Media



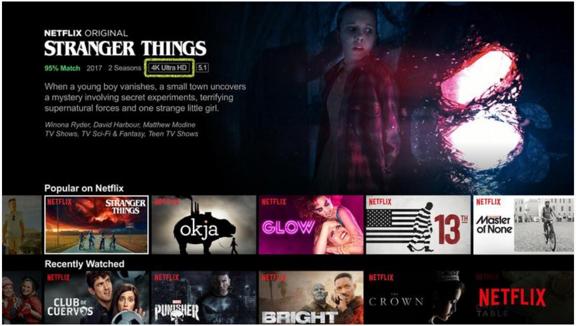
Late 1990s: Digital Television and DVD emerges. Compression standards like JPEG and MPEG2 are established.

The Rise of Digital Media

MP3, MPEG4, QuickTime Video Format, FLV, etc.

2000s: Video on mobile phones / video over internet/ HDTV / 3DTV

The Rise of Digital Media



Now: Online streaming of high quality Video (incl. 4k) (Netflix, Youtube etc.)

Consolidation around 2 main compression standards: MPEG (h264, h265, etc.) and Alliance for Open Media (vp9, av1, etc.)

Why Compression?

Why Compression?

In the days of **standard definition** TV, the resolution was 720×576 pixels, with 3 colours per pixel ($3 \times 8 = 24$ bits per pixel) at 25 fps.

Let's look at the bandwidth of some uncompressed streams:

SD $= 720 \times\ 576 \times 24\text{bpp} \times 25\text{ fps}\ \approx 250 mbps$

HDTV $= 1920 \times\ 1080 \times 24\text{bpp} \times 60\text{ fps}\ \approx 3 gbps$

UHDTV $= 3840 \times\ 2160 \times 24\text{bpp} \times 60\text{ fps}\ \approx 12 gbps$

3D Cinema $= 4096 \times\ 2160 \times 36\text{bpp} \times 48\text{ fps}\ \times 2 \approx 30 gbps$

Why Compression?

By 2022, video viewing will account for 82% of all internet traffic. (CISCO)

Internet traffic accounts for more than 1% of global emissions.

Data centres accounts for more than 1% of global emissions.

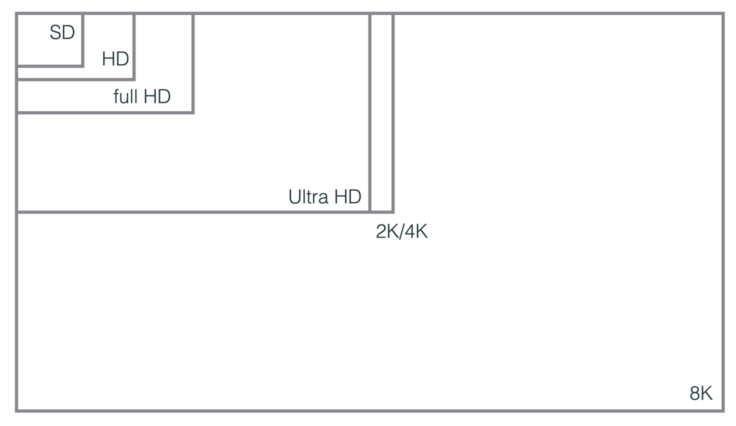
1% improvement on compression means Billions of $ in bandwidth savings and significant reductions on global emissions.

Why Compression?

Will Bandwidth ever catch up?

probably not,

Why Compression?



Youtube has been streaming in 8K for some years now...

Why Compression?

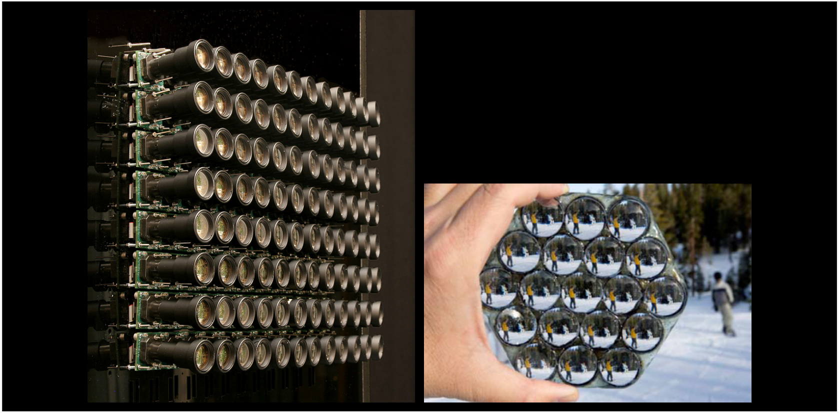
HDRTV (12+ bit per channel) has also been here for some time.

Why Compression?

Virtual Reality's sweet spot is probably 16K at 120fps in Stereo 3D.

`raw bandwidth ≈ 1tbps`

Why Compression?



Lightfield cameras (capturing light from all angles) will probably be the next revolution.

`raw bandwidth` $\approx$ `14tbps`

Why Compression?

Compression is ubiquitous:

Digital Cameras have built in compression on the chip itself. Even for top of the range cameras like Arri and Red.

Cinema PostProduction Companies store images using lossless image compression (EXR file format).

When working with images, the main consideration are memory cache and data bandwidth between GPU and CPU.

Videos are just big.

Books and Links

Digital Image Processing. Gonzalez and Woods. Prentice Hall (a good general purpose image processing text book)

JPEG: Still Image Processing Standard. Pennebaker and Mitchell. Van Nostrand Reinhold. (a reference for JPEG)

Digital Video: An Introduction to MPEG2. Haskell, Puri and Netravali. Chapman and Hall (a reference for MPEG2)

Engineering Blogs from YouTube and Netflix:

https://youtube-eng.googleblog.com/

http://techblog.netflix.com/