Video

4C8: Digital Media Processing

Ussher Assistant Professor François Pitié

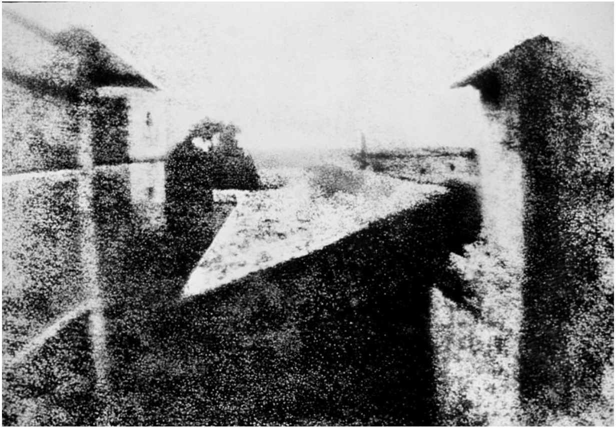
2022/2023

Department of Electronic & Electrical Engineering , Trinity College Dublin

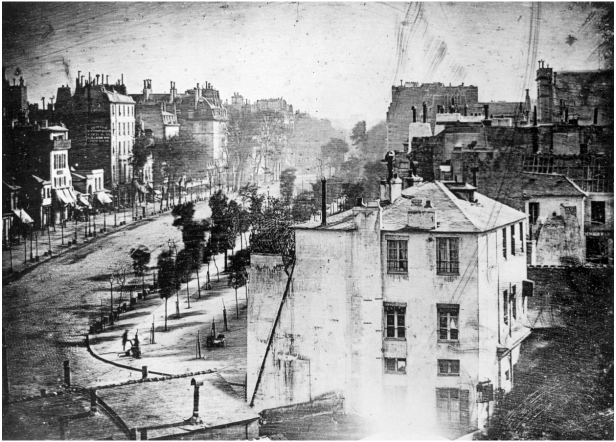
A Cinema and TV History

Cinema is just over 100 years old.

1816: First Photograph by Nicéphore Niépce. Took 8h+ exposure.

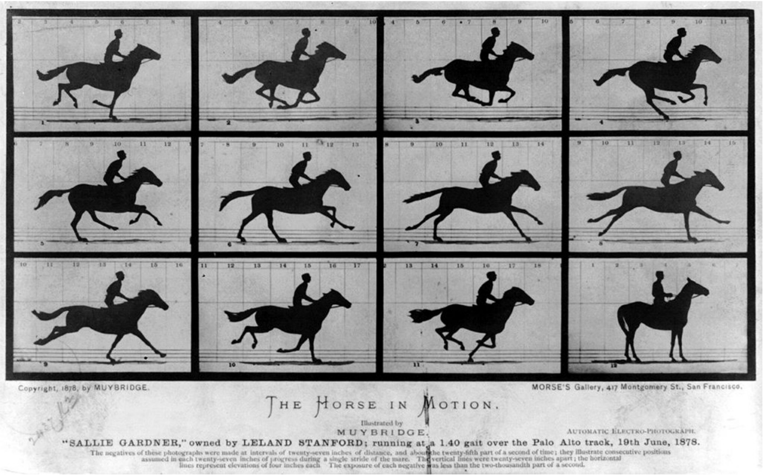


1838: Daguerre continued work from Niépce to bring down exposure to minutes.



A Cinema History

1872: First Moving images in 1872 because of a bet on a horse: does a horse have all four hooves off the ground at any stage of its trot?

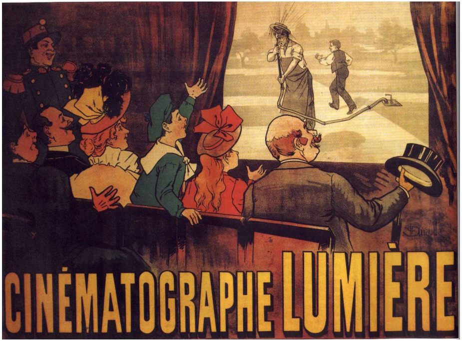


https://www.youtube.com/watch?v=wNU7sXkZmSw

A Cinema History

1889: Edison develops a camera using celluloid film.

1895: birth of cinema. Auguste and Louis Lumière show their films to a paying audience in Paris.



1900's: first dedicated movie theatres

A History of TV

1873: Willoughby Smith discovers the photoconductivity of selenium

1884: Gottlieb Nipkow proposes to rasterise images with a mechanical spinning disk.

1923: John Logie Baird develops the first mass produced complete TV system, using a Nipkow disk.

1927-20s: Philo Farnsworth/Vladimir Zworykin (dispute) develop all electronic TV using Cathode Ray Tubes (CRT).

`https://www.youtube.com/watch?v=uM7ZD5f9Pb8`

`https://www.youtube.com/watch?v=rjDX5ItsOnQ`

A History of TV

1936: BBC launches first regular “high Definition” TV service.

1953: 3M viewers follow the coronation on TV. TV becomes a mass media.

1954: Colour TV starts in the USA (NTSC), for the wealthy...

1967: SECAM and PAL systems

Analogue TV: Recording

Methods for storing TV signals on magnetic tape came along after TV was invented ...Bummer! For a long while Broadcasters were using cinema film cameras to record the TV screens, in an (insane) process called telecine.

Analogue TV: Recording

1950: RCA introduced longitudinal tape 6m/sec. Early tapes used to be made of steel and burst a lot — a bit scary.

1956: Ampex corporation proposed the first technologically viable solution: 2 inch magnetic tape spinning at 14,000 rpm(!)

1972: Philips home video

1978: Betamax (Sony) Vs VHS (Panasonic)

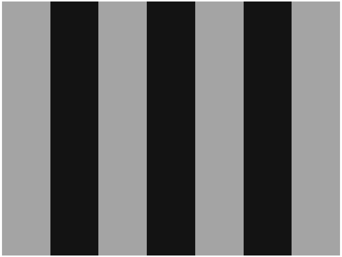
1980: VHS standard

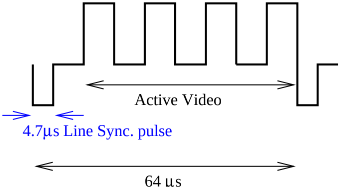
1995: Digital Betacam, Digital-S [Broadcast]

1998: DVD and Digital

2007: HD, DV, Blu-Ray, HDV

Analogue TV: Signal Anatomy





Left: a single frame from a b/w video sequence showing 4 vertical white bars. Right: the **PAL** video signal of a single line from the frame on the left.

Analogue TV: Signal Anatomy

For black and white video, the active line part of the video signal is simply the space varying Y component. For colour pictures, the colour components are encoded using Quadrature Amplitude Modulation (QAM) to create a composite video signal:

NTSC:

$$c = Y + U\sin(\omega t + 33^\circ) + V\cos(\omega t + 33^\circ)$$

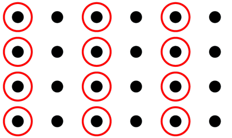
PAL:

$$c = Y + U\sin(\omega t) + V\cos(\omega t)$$

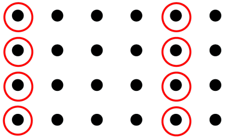
Note that SECAM uses frequency modulation instead of amplitude modulation.

Analogue TV: Signal Anatomy

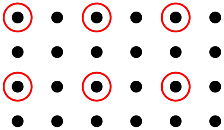
Colour information is typically sampled at a lower rate than the intensity information. Typical sampling structures used for colour digital video formats include:



4:2:2



4:1:1



4:2:0

Luminance samples are black dots, colour samples are indicated by red circles.

Interlacing vs. Progressive

TV formats take advantage of the persistence of human vision by using an *interlaced* scanning pattern in which the odd and even lines of each picture are read out alternatively, allowing for a doubling of the framerate, at the expense of the spatial resolution.

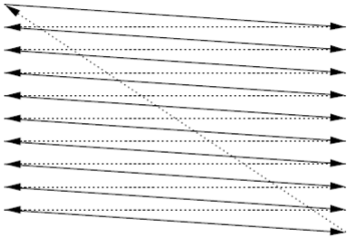


Figure 4: Progressive (Sequential) TV scanning

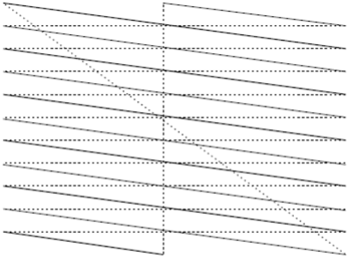


Figure 5: Interlaced TV Scanning

Interlacing vs. Progressive

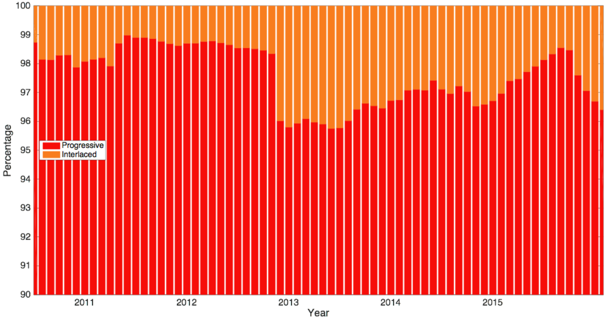
even field (captured at time t)

odd field (captured at time $t + 1$)

combined displayed interlaced frame at time $t+1$.

Interlacing vs. Progressive

Interlacing is still with us. This legacy TV broadcast practice still accounts for 2-3 percents of the content uploaded to YouTube.



source: YouTube Engineering Blog Post on Upload Statistics https://bit.ly/3ic9kQ2

NTSC vs. PAL

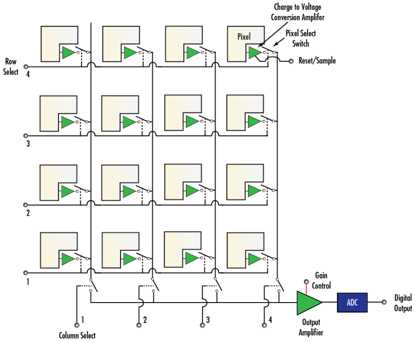
	PAL	NTSC
Number of Lines	625 (576 visible)	525 (480 visible)
framerate	25	30
interlaced	Yes (50 Hz)	Yes (60 Hz)
Colour Space	$\begin{bmatrix} Y' \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.14713 & -0.28886 & 0.436 \\ 0.615 & -0.51499 & -0.10001 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$	$\begin{bmatrix} Y' \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.595716 & -0.274453 & -0.321263 \\ 0.211456 & -0.522591 & 0.311135 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$

Anatomy of Modern Recording Devices

CMOS sensor

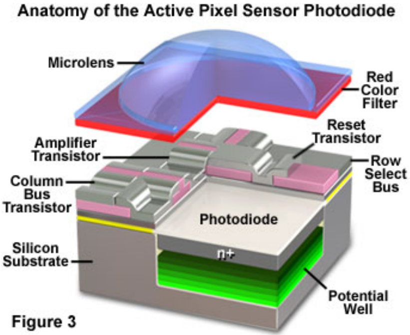
Until the mid-2000s, most cameras were fitted with CCD sensors. But since then CMOS technology has outgrown and outpaced CCD and most cameras you will work with use CMOS.

With CMS, each pixel site is essentially a photodiode and three transistors, performing the functions of resetting or activating the pixel, amplification and charge conversion, and selection or multiplexing:



Modern Recording Devices: CMOS sensor

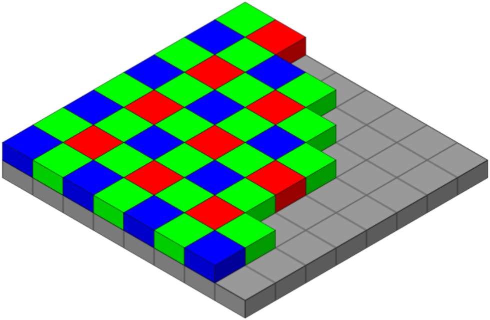
Note that the amplifier/bus/reset transistors take a large portion of the sensor area, leaving only about 30% for the light sensitive area. Each pixel is thus fitted with a micro lens, so that the active area can effectively capture 90% of the light.



Note that each pixel is also fitted with a colour filter.

Bayer Pattern

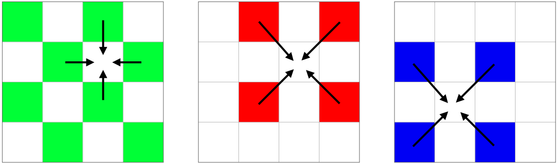
To obtain colour images, image sensors are indeed organised in a *colour filter array*. The most popular is the Bayer pattern:



The *colour filters* are laid out such as to mimick the cones in the human eye retina, using twice as many green elements as blue or red.

Bayer Pattern: Demosaicing

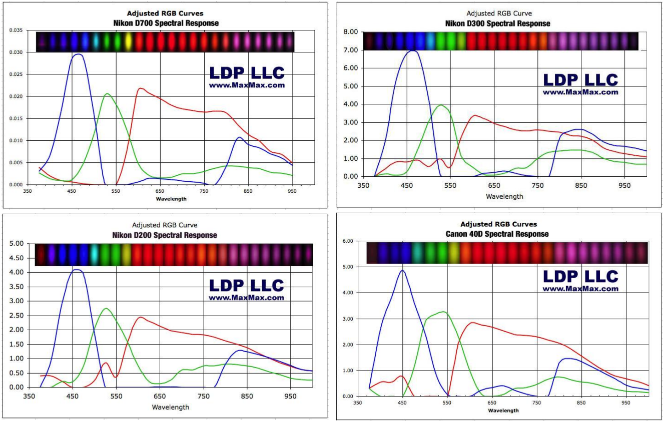
A problem is that we are missing colour information: no pixel has the three R,G and B components. The missing R, G, B values must be interpolated from surrounding values using a **demosaicing** algorithm.



This is actually a hard problem, and part of the progress in picture quality over the past years comes from the improvement demosaicing software.

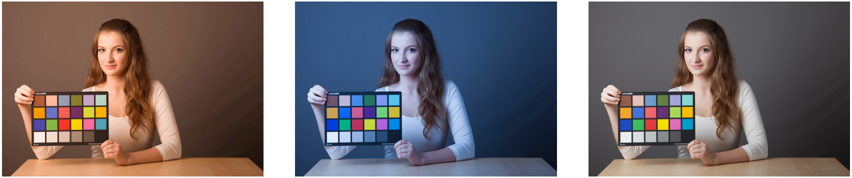
Spectral Response

The combination of the sensor specs and colour filters used yield a specific spectral response for each sensor (remember the LMS cones?):



That will need to be converted into sRGB colour space.

White Balance



Attr: Alex1ruff, CC BY-SA 4.0, via Wikimedia Commons

Real light sources (*e.g.* sunlight, incandescent bulbs, and fluorescent lighting) tend to be interpreted by the HVS as white, when, in fact, they emit light of different colours.

White balance is the process of making the colours appear more correct to the human eyes, *e.g.* removing the red cast of incandescent lighting. White balance is a linear colour transform:

$$R' = \frac{255}{R_W} R \,, \quad G' = \frac{255}{G_W} G \,, \quad B' = \frac{255}{B_W} B$$

where R_W, G_W, B_W is the colour of “white”.

Rolling Shutter

An issue related to CMOS is the so called *rolling shutter*. This is due to the multiplexing configuration of the CMOS sensor, which is such that rows are read in sequence, one at a time. This means that there is a time delay between the capture of the top and bottom row. This can cause distortion artefacts in case of fast motion:

Note: *CCD* sensors do not suffer from this artefact.

Optical Anti-Aliasing Filter

Before the sensor, cameras are usually fitted with an optical Anti-Aliasing Filter, which is simply put a piece of glass that blurs the image, so as to cut off frequencies at the Nyquist freq and avoid aliasing due to the sampling process of the sensor.

The (in-camera) image processing pipeline

- Gain Amplifier
- Analogue to Digital Conversion
- correct for sensor bias (adjust the black levels)
- fix dead pixels
- vignetting compensation
- white balance
- demosaicing
- denoising
- colour space conversion
- tone reproduction
- color space conversion to YCbCr
- apply 4:4:4, 4:2:2 subsampling
- compression