On Audio-Visual File Formats

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On the Materiality of Audio-Visual Heritage
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Donostia (San Sebastián), Spain
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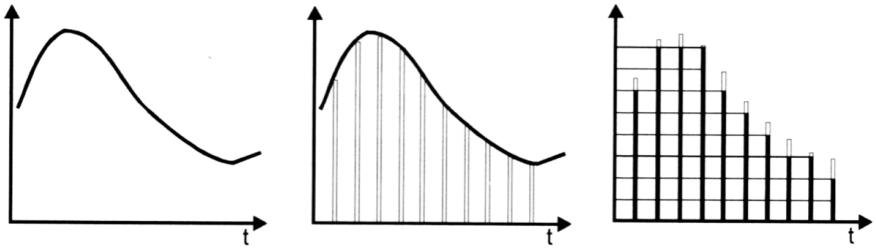
Summary

- digital audio and digital video
- container, codec, raw data
- different formats for different purposes
- audio-visual data transformations

Digital Audio

Digital Audio

- sampling
- quantisation



digitisation = sampling + quantisation

Sampling

- 44.1 kHz
- 48 kHz
- 96 kHz
- 192 kHz
- 500 kHz

Quantisation

- 16 bit (2^{16} = 65 536)
- 24 bit (2^{24} = 16 777 216)
- 32 bit (2^{32} = 4 294 967 296)

Digital Video

Digital Video

- resolution
- bit depth
- linear, power, logarithmic
- colour model
- chroma subsampling
- illuminant

Resolution

- SD 480i / SD 576i
- HD 720p / HD 1080i
- 2K / HD 1080p
- 4K / UHD-1
- 8K / UHD-2

Bit Depth

- 8 bit ($2^8 = 256$)
- 10 bit ($2^{10} = 1\,024$)
- 12 bit ($2^{12} = 4\,096$)
- 16 bit ($2^{16} = 65\,536$)
- 24 bit ($2^{24} = 16\,777\,216$)

Linear, Power, Logarithmic

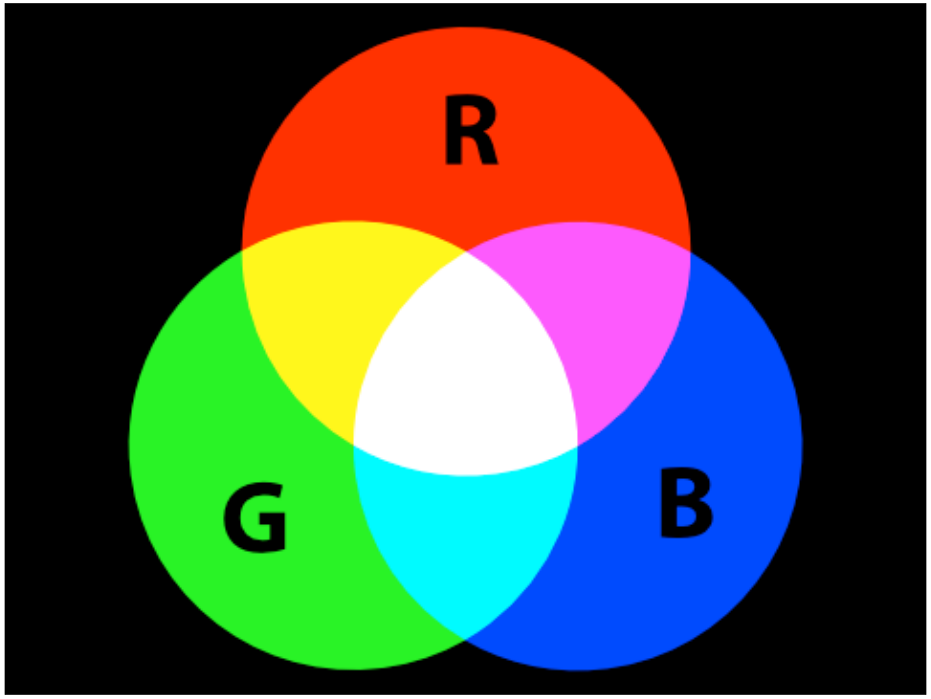
«medium grey»

- linear: 18%
- power: 50%
- logarithmic: 50%

Colour Model

- XYZ, L*a*b*
- RGB / R′G′B′ / CMY / C′M′Y′
- Y′IQ / Y′UV / Y′D_BD_R
- Y′C_BC_R / Y′C_OC_G
- Y′P_BP_R

13



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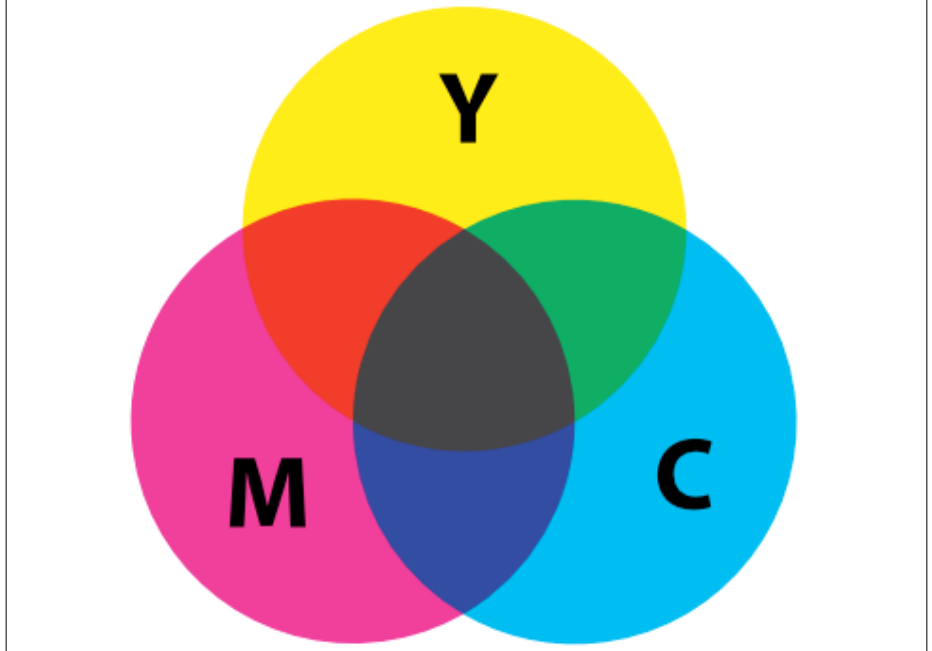


15

16

RGB24

```
00000000 11111111 00000000 00000000
00000000 00000000 11111111 00000000
00000000 00000000 00000000 11111111

00000000 11111111 11111111 11111111
11111111 00000000 11111111 11111111
11111111 11111111 00000000 11111111
```


Compression

- uncompressed
- lossless compression
- lossy compression
- chroma subsampling
- born compressed

Uncompressed

+ data simpler to process
+ software runs faster
− bigger files
− slower writing, transmission and reading

Examples: TIFF, DPX, DNG, OpenEXR

Lossless Compression

+ smaller files
+ faster writing, transmission and reading
− data processing complexer
− software runs slower

Examples: JPEG 2000, FFV1

Lossy Compression

- optimised for image acquisition and/or postproduction
- optimised for access

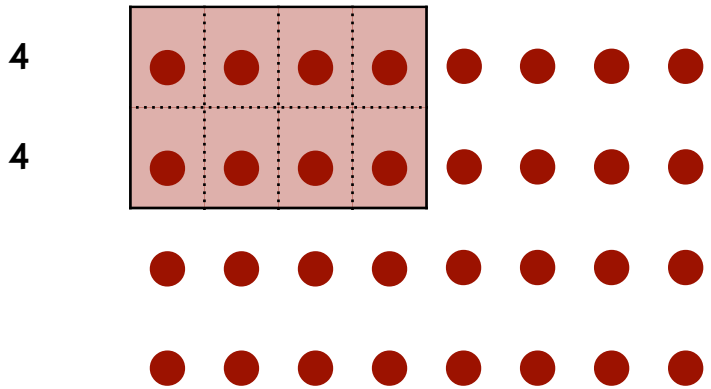
Examples (mezzanine): ProRes 422, ProRes 4444, DNxHD, DNxHR

Examples (access): H.264 (AVC), H.265 (HEVC), AV1

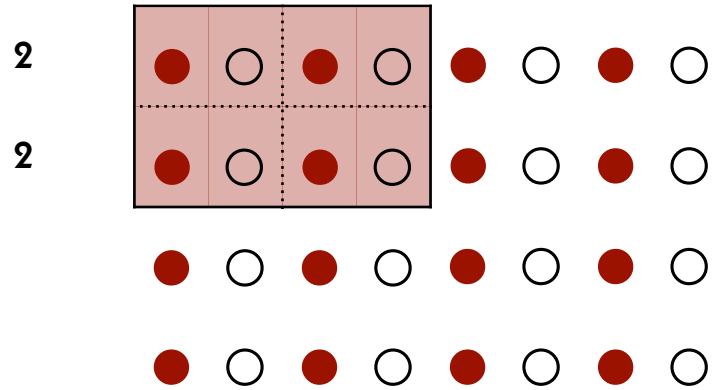
Chroma Subsampling

- 4:4:4
- 4:2:2
- 4:2:0 / 4:1:1

4:4:4

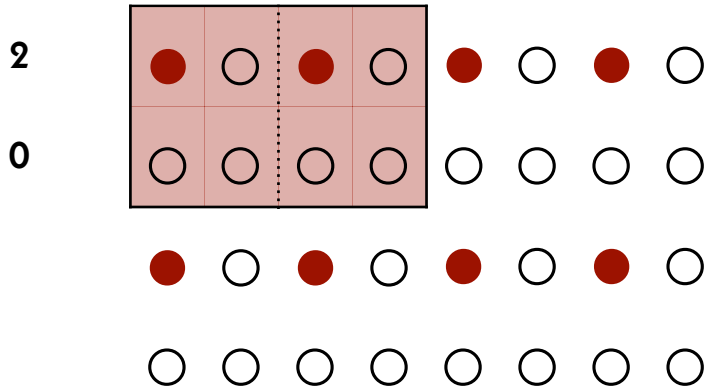


4:2:2



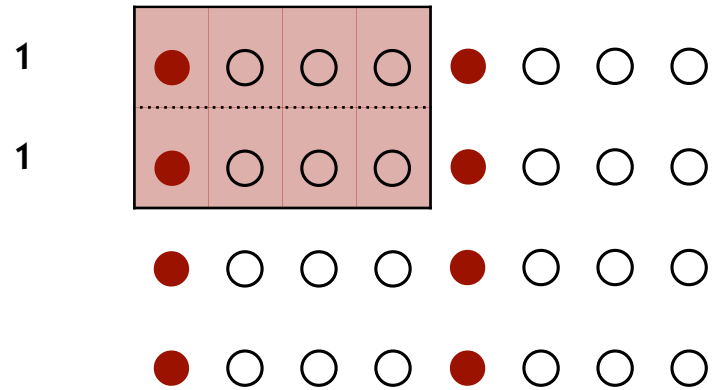
25

4:2:0



26

4:1:1



27

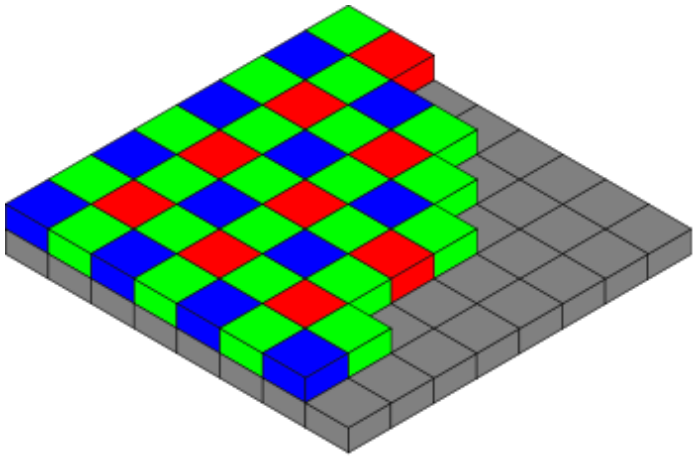
Born Compressed

- optimised for both image acquisition and postproduction

Examples: CineForm RAW, ProRes RAW

28

Bayer



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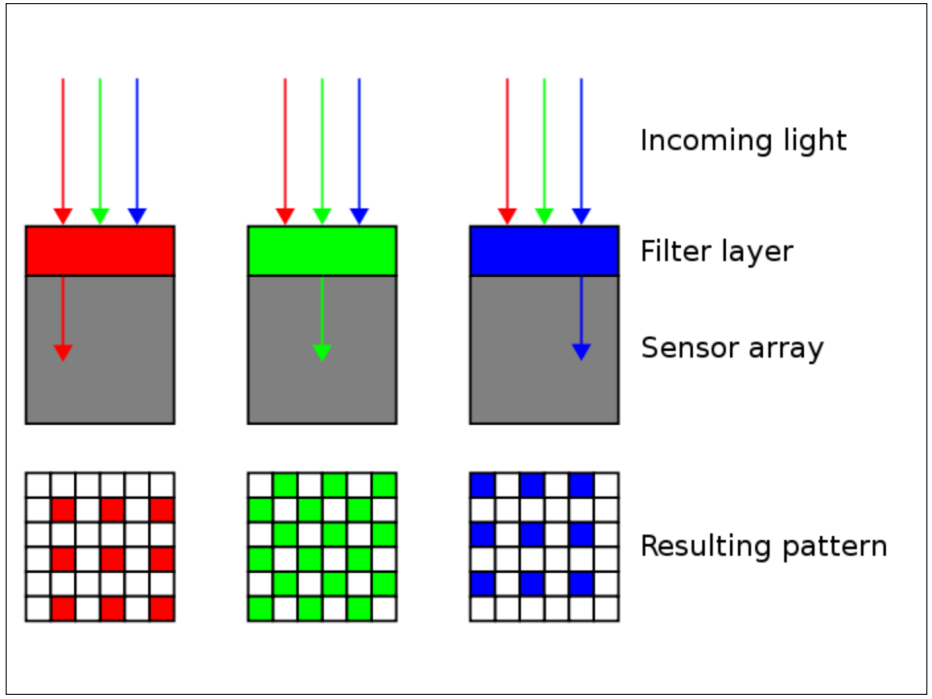

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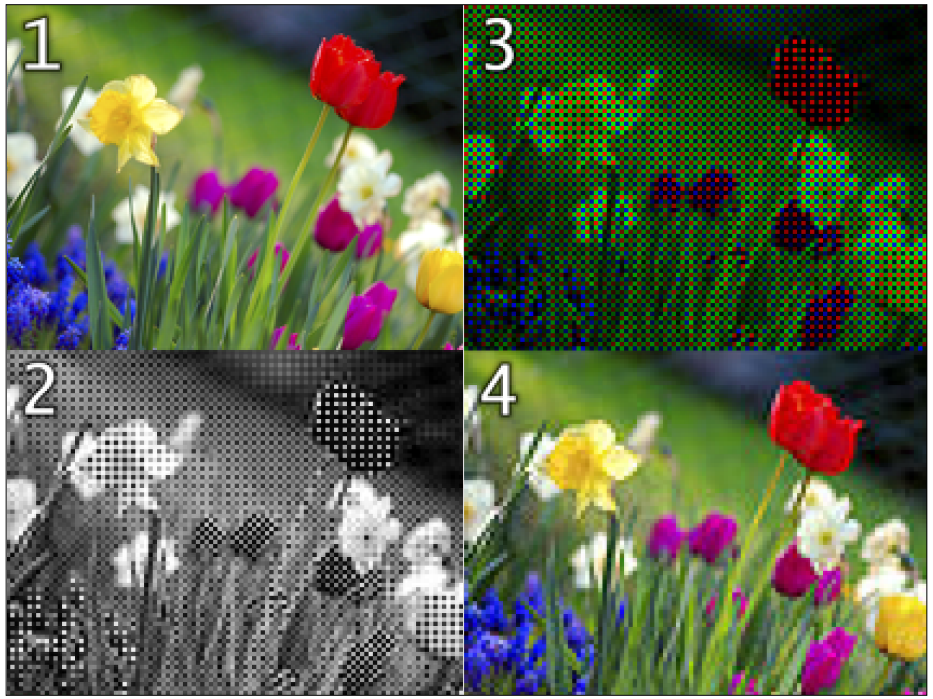

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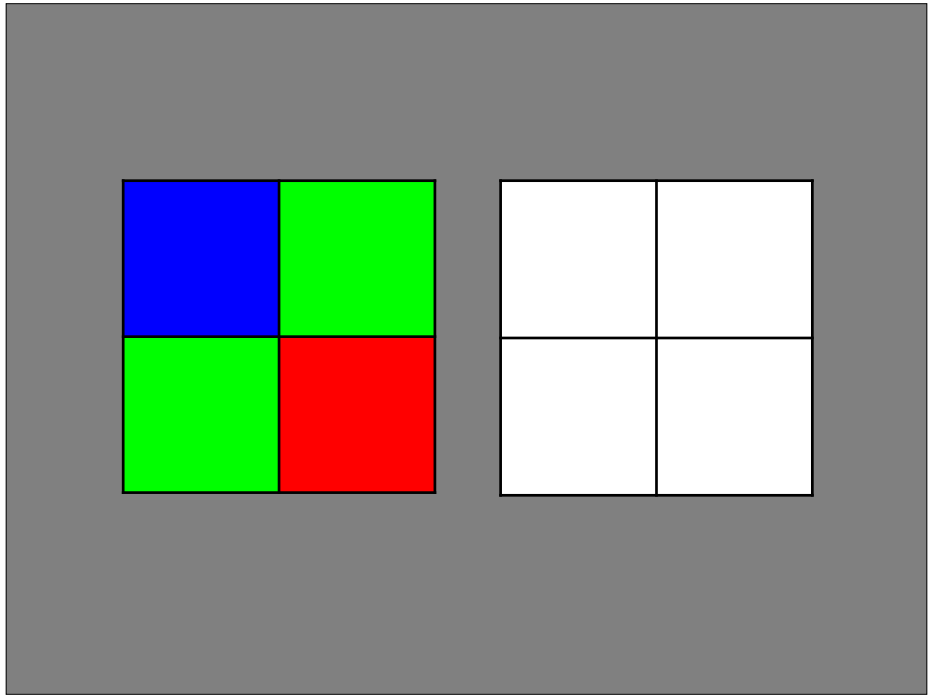
01001101010101010101000010111010100
01110101001010101000101101010111100
00011101010101010101000010111010100
01101010100101010100010110101011110
00101010101010101000010111010100000
01110101001010101000101101010111100
01010101010101010000101110101001100
10010111010100101010100010110101010
11100101010101010100001011101010100
01110101001010101000101101010111100
01010101010101010011010101000000010
00101000101010101010010101010101010
```

32



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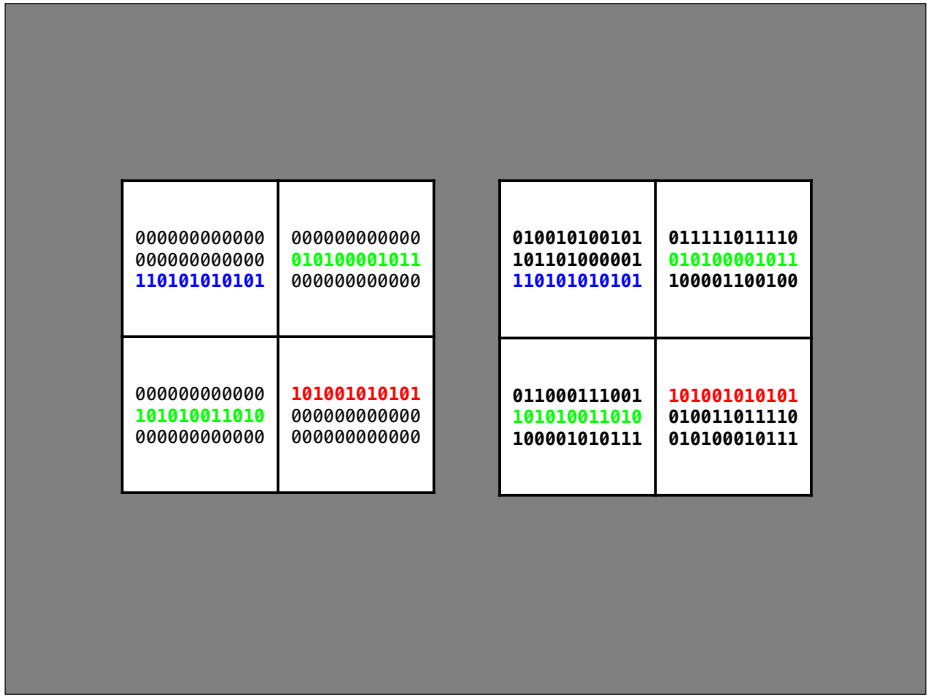
000000000000
000000000000
110101010101
000000000000
010100001011
000000000000
010010100101
101101000001
110101010101
011111011110
010100001011
100001100100
000000000000
101010011010
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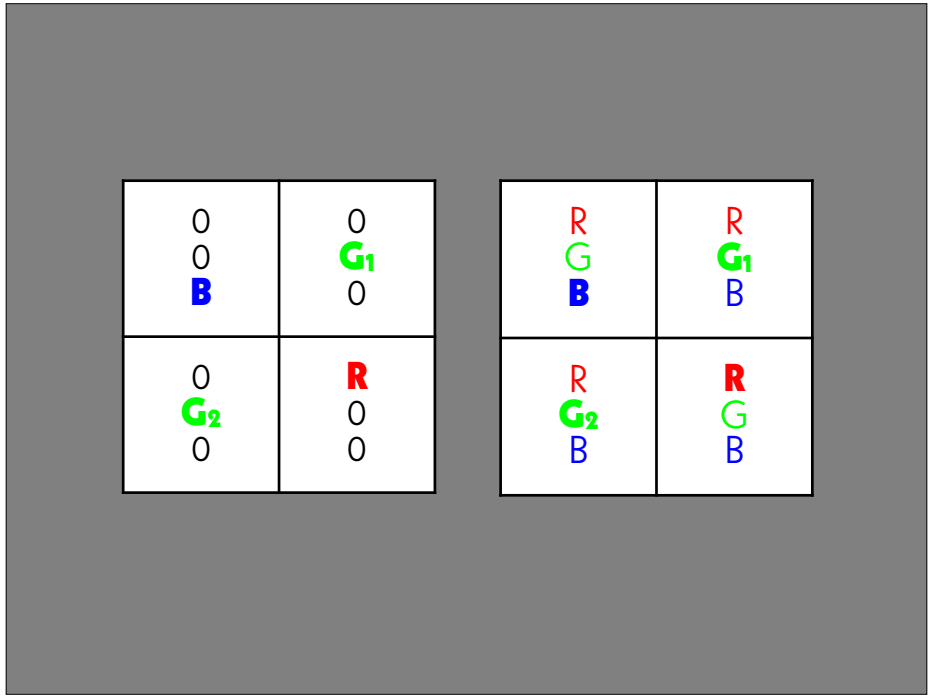
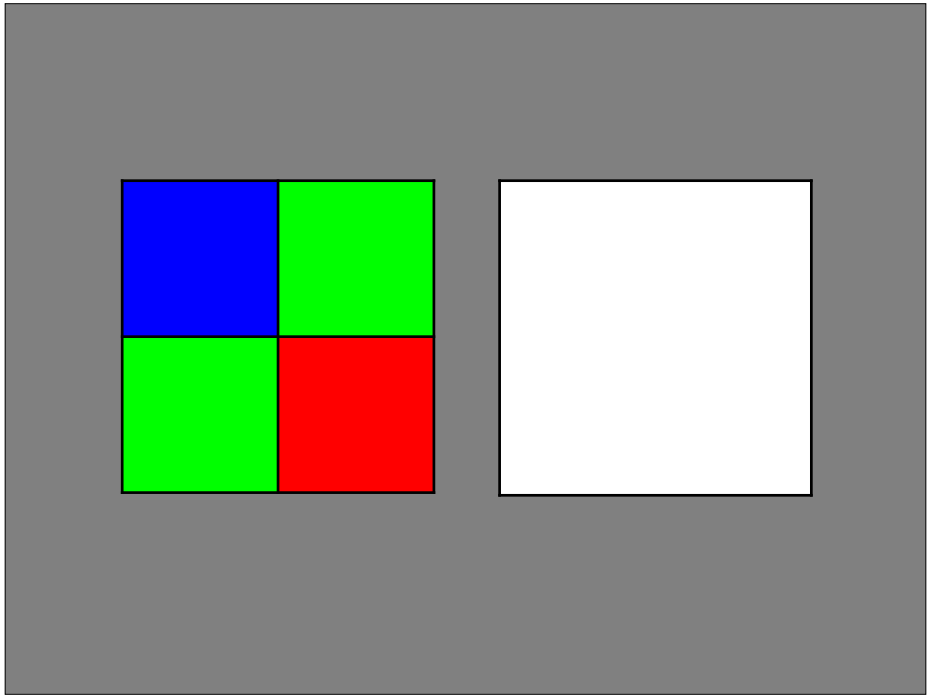
100001010111
101001010101
010011011110
010100010111

34


0
0
B
0
G1
0
0
G2
0
R
0
0
R
G
B
R
G1
B
R
G2
B
R
G
B

35



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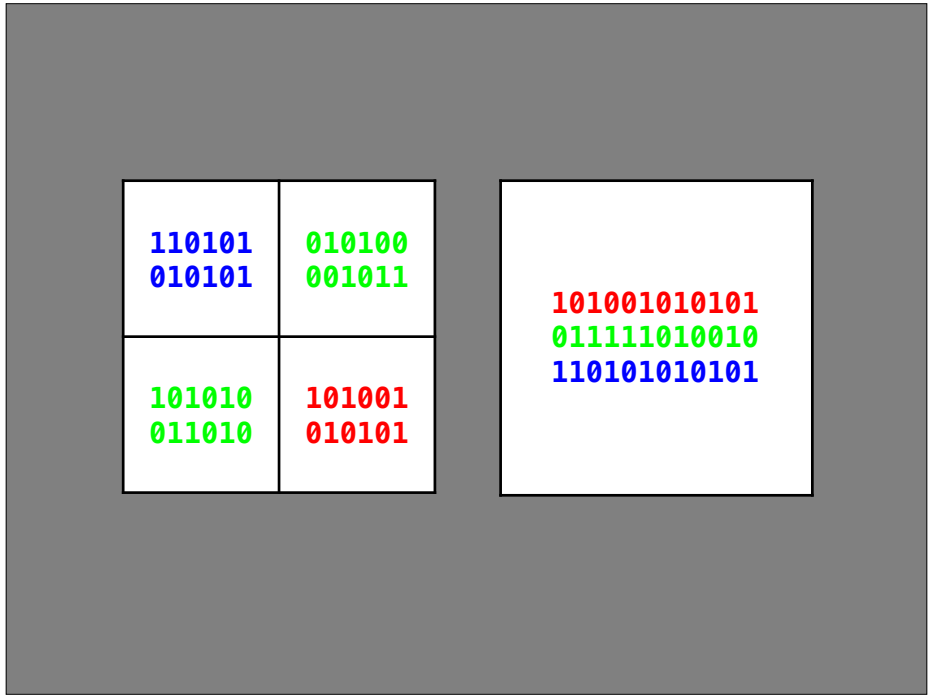
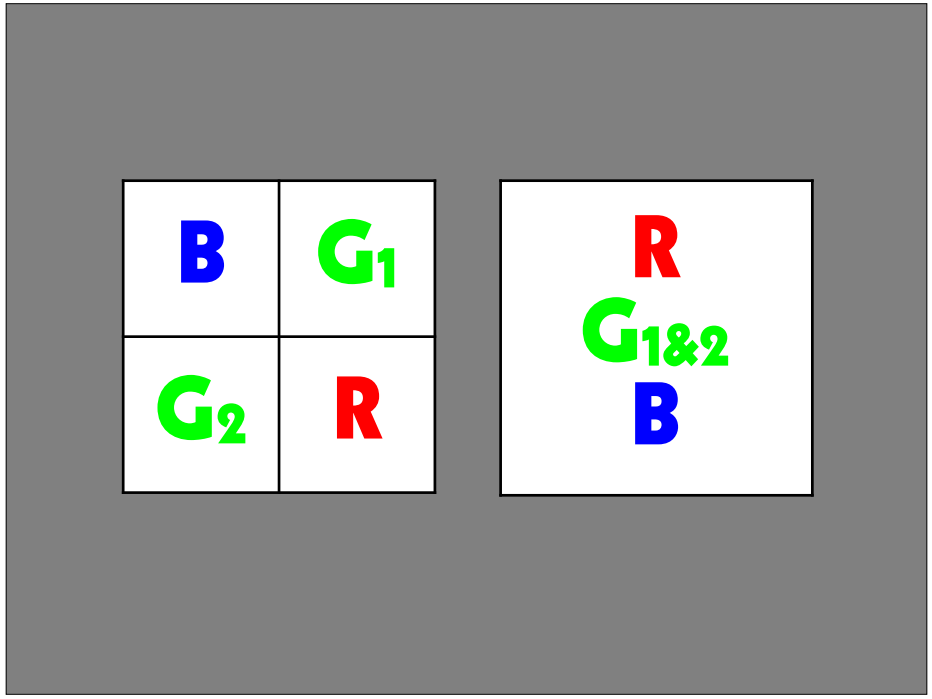


37



38

Two ways to use Bayer data

digital blow-up to RGB

- 3 times the amount of the generated data
- the file has the full sensor resolution
- only ⅓ of the data are real

digital reduction to RGB

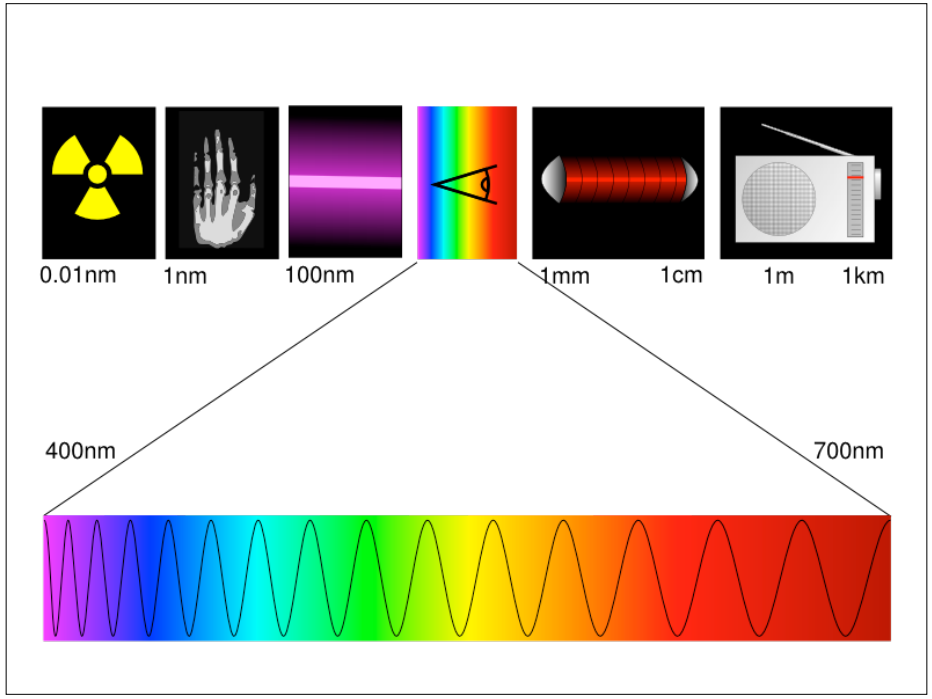
- ¾ the amount of the generated data
- the file has ½ of the sensor resolution
- all data are real

39

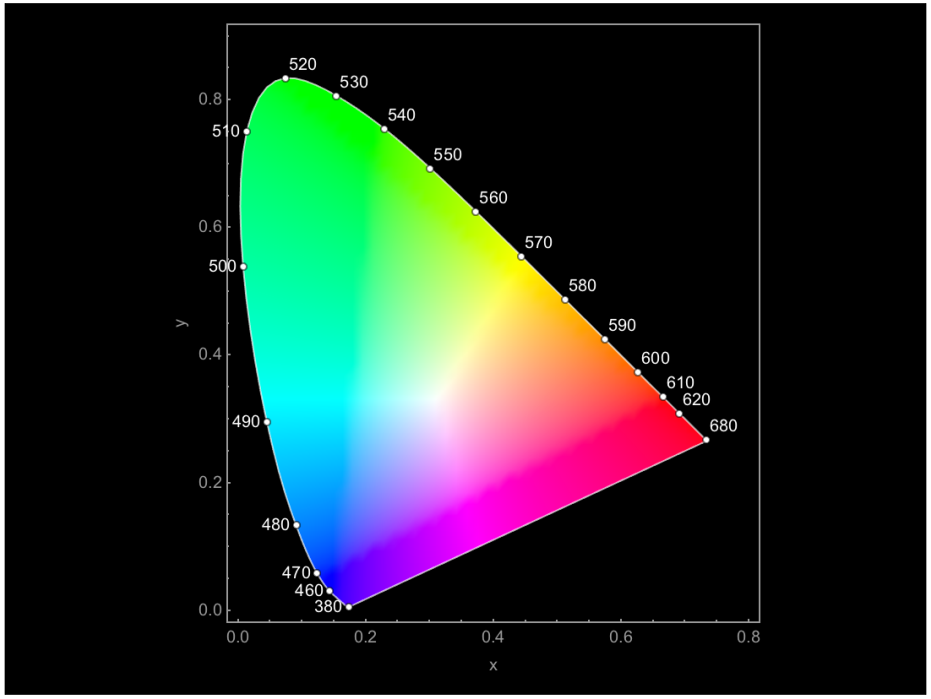
Illuminant

- D50
- D55
- D65
- D75

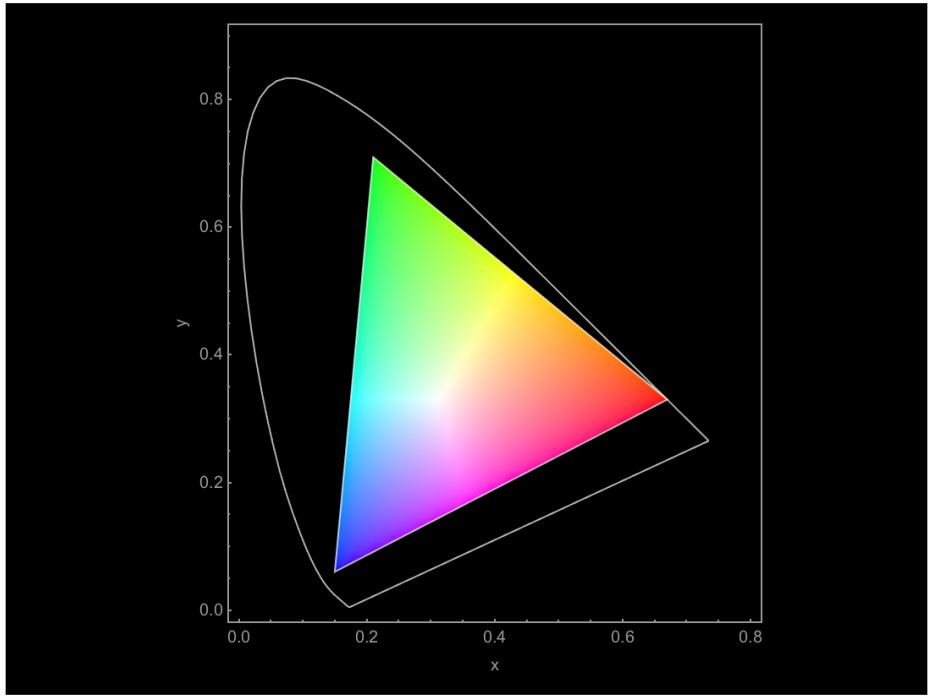
40


0.01nm
1nm
100nm
1mm
1cm
1m
1km
400nm
700nm

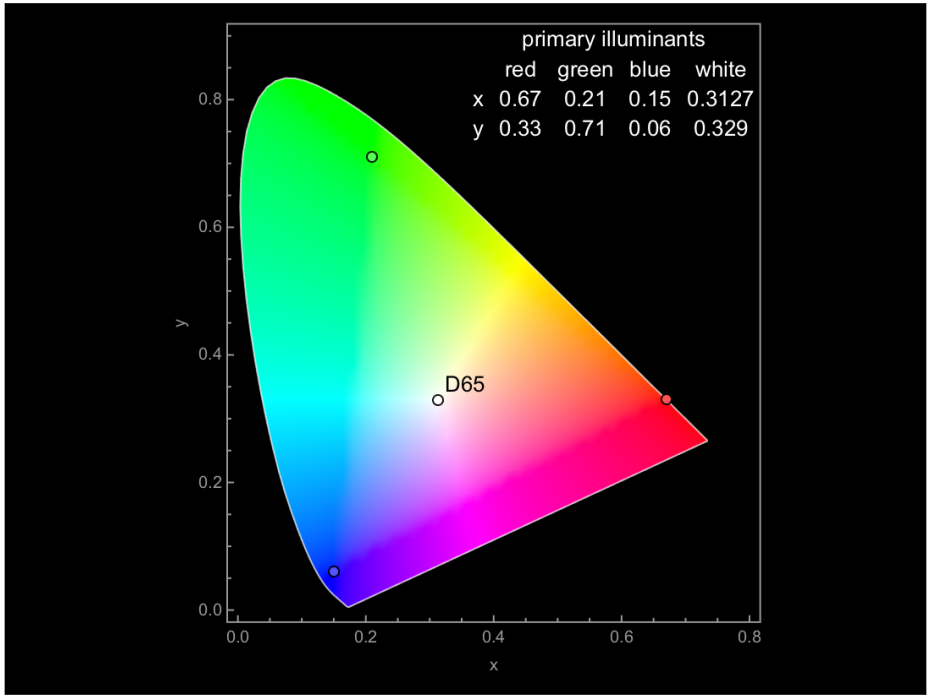
41


520
530
540
550
560
570
580
590
600
610
620
680
510
500
490
480
470
460
380
0.0
0.2
0.4
0.6
0.8
x
y

42


0.0
0.2
0.4
0.6
0.8
x
y

43

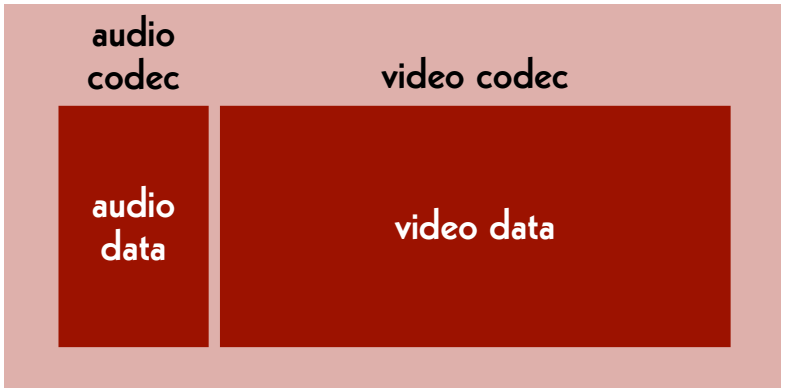

primary illuminants
red green blue white
x 0.67 0.21 0.15 0.3127
y 0.33 0.71 0.06 0.329
D65
0.0
0.2
0.4
0.6
0.8
x
y

44

File Structure

File Structure

audio-visual container (wrapper)



Audio-Visual Container

- MP4
- MOV
- AVI
- MXF
- Matroska (.mkv)
- Flash

Single Images

- folder
- TAR
- ZIP
- MXF
- Matroska (.mkv)
- CinemaDNG

Audio Codec

- WAVE
- BWF
- FLAC
- AAC
- MP3

Video Codec (Master)

images

- TIFF
- DPX
- JPEG 2000
- OpenEXR
- DNG

streams

- 8 bit raw
- 10 bit raw
- HuffYUV
- FFV1

Video Codec (Mezzanine)

- ProRes 422, ProRes 4444, ProRes RAW
- DNxHD, DNxHR
- CineForm RAW

Video Codec (Access)

- H.264, H.265 (HEVC), AV1

Data is anything but «raw».

Audio Data

- pcm_s16le
- pcm_s24le
- pcm_s32le

Video Data

- rgb48le
- rgb24
- rgb72le
- bayer_bggr16le
- bayer_bggr24le
- yuv444p16le
- yuv422p10le
- uyvy422
- yuv420p
- yuv444p24le

What is inside my DPX?

- log neg encoding
- log RGB encoding or quasi-log encoding
- gamma encoding or power function encoding
- scene-linear encoding

File Formats

Principles

- **The archive must be able to handle the file formats it holds.**

- open source
- simple to use and well documented
- widely used by the community

Different Purposes

archive master format:
➔ for preservation

mezzanine format:
➔ for professional use in post-production

dissemination formats:
➔ for widely spreading and easy access

Elena Rossi-Snook:

Archiving without access isn't preservation, it's hoarding.

Archive Master (Today)

film
- folder, TIFF, 2K, RGB, 4:4:4, 16 bit
- MXF, DPX, 2K, R'G'B', 4:4:4, 10 bit

video
- AVI, «raw», HD, $Y'C_BC_R$, 4:2:2, 10 bit
- Matroska, FFV1, HD, $Y'C_BC_R$, 4:2:2, 10 bit

audio
- BWF, 96 kHz, 24 bit
- FLAC, 96 kHz, 24 bit

Mezzanine (Today)

video
- ProRes 4444, 2K
- DNxHR, 2K
- ProRes 422 HQ, HD
- DNxHD 175x, HD

audio
- BWF, 48 kHz, 24 bit
- WAVE, 48 kHz, 24 bit

Dissemination (Today)

MP4

Video
- H.264, SD, yuv420p, «lossy»
- H.264, HD, yuv420p, «lossy»

Sound
- AAC, 44.1 kHz, 16 bit
- AAC, 48 kHz, 16 bit

Archive Master and Mezzanine

film
- Matroska, FFV1, 2K, «RGB», 4:4:4, 16 bit

video
- Matroska, FFV1, HD, $Y'C_BC_R$, 4:2:2, 10 bit

audio
- Matroska, FLAC, 96 kHz, 24 bit

Access

WebM (a subset of Matroska)

Video

- «H.265», HD, yuv420p
- AV1, HD, yuv420p

Sound

- FLAC, 48 kHz, 16 bit

Pros & Cons

container:

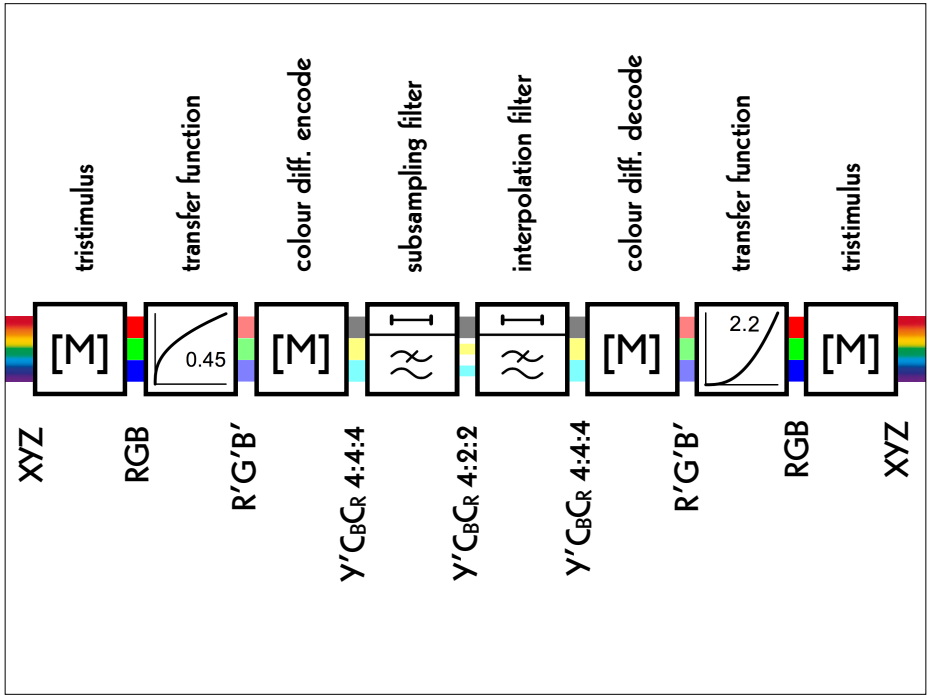
- folder
- TAR
- ZIP
- MXF
- Matroska

codec:

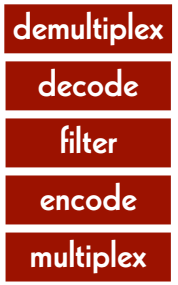
- TIFF
- DPX
- JPEG 2000
- FFV1
- OpenEXR
- CineForm RAW
- ProRes RAW

	avantages	**disavantages**
TIFF DPX OpenEXR	data easier to process	bigger files
JPEG 2000 FFV1	smaller files	data complexer to process

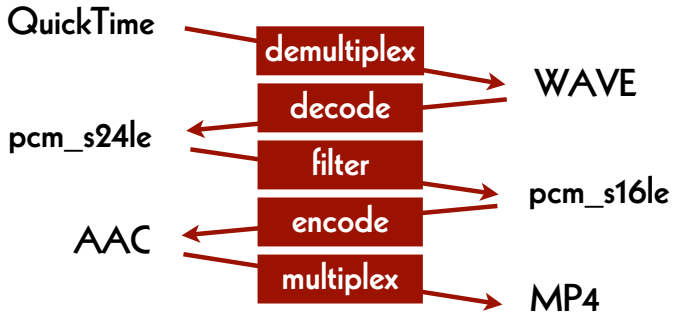
Transformations



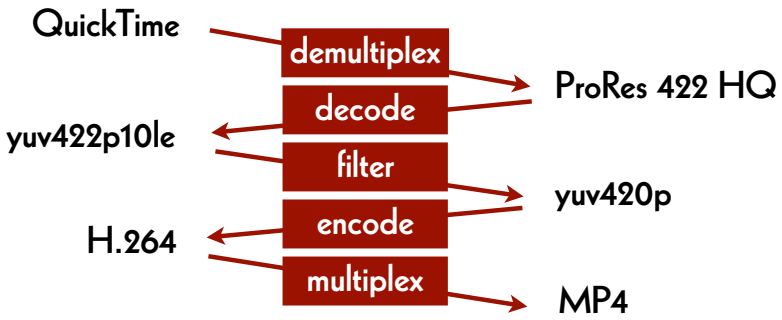
Data Transformations



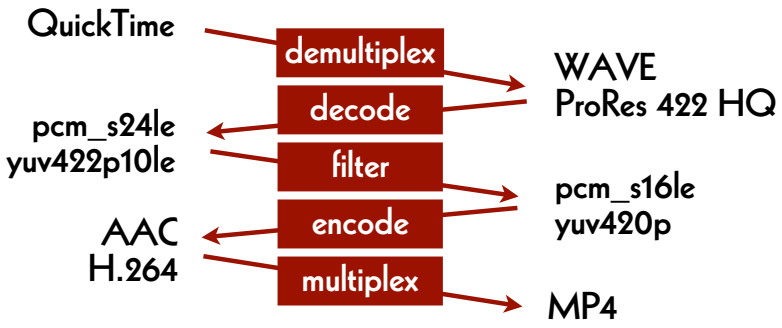
Audio Exemple



Video Exemple



Audio-Visual Exemple



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