Audiovisuelle Dateiformate

Reto Kromer • AV Preservation by reto.ch

Weiterführender Memoriav-Workshop
Automatisierung von FFmpeg mit Bash
Lichtspiel, Bern, 12. Januar 2023

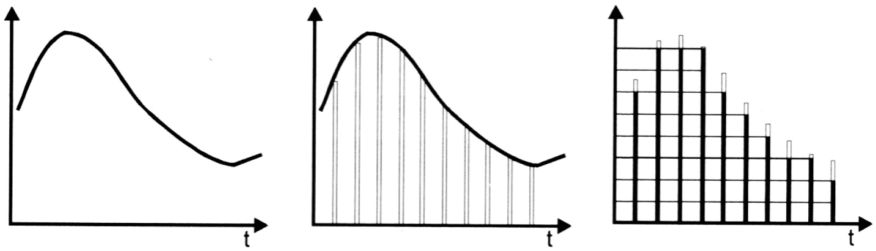
Inhalt

- digitaler Ton und digitales Bild
- Container, Codec, Rohdaten
- verschiedene Formate für unterschiedliche Zwecke
- audiovisuelle Dateiumwandlungen

Digitaler Ton

Digitaler Ton

- Abtastung
- Quantisierung
- Kompression



Digitalisierung = Abtastung + Quantisierung

Abtastung

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

Quantisierung

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

Digitales Bild

Digitales Bild

- Auflösung
- Quantisierungsauflösung
- linear, Potenzfunktion, logarithmisch
- Farbraum
- Kompression und Farbunterabtastung
- Normlicht

Auflösung

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

Quantisierungsauflösung

- 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 ($2^{24} = 16\,777\,216$)

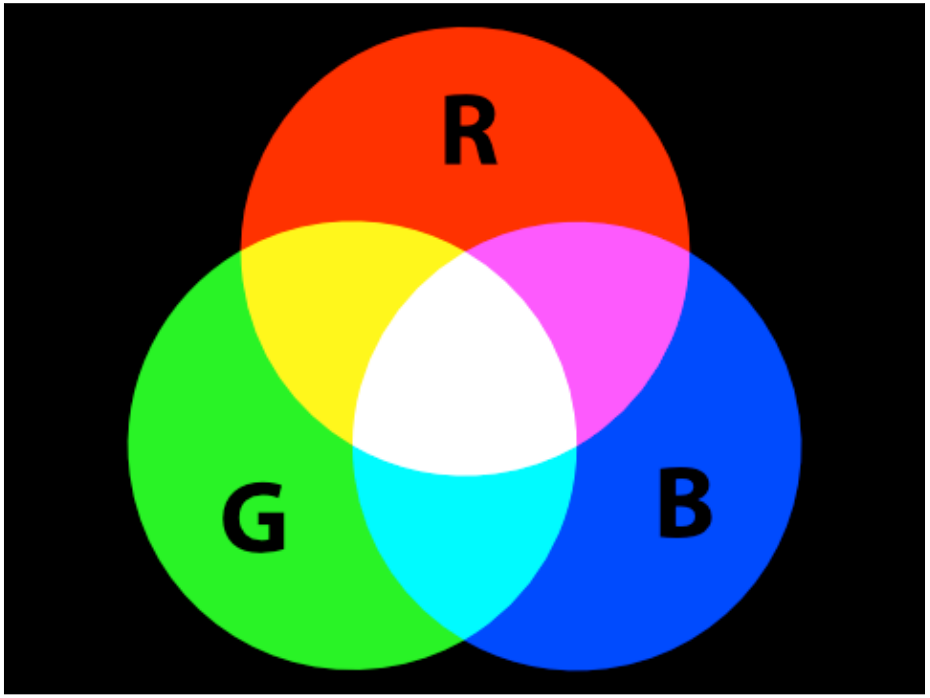
Linear, Potenz, Logarithmus

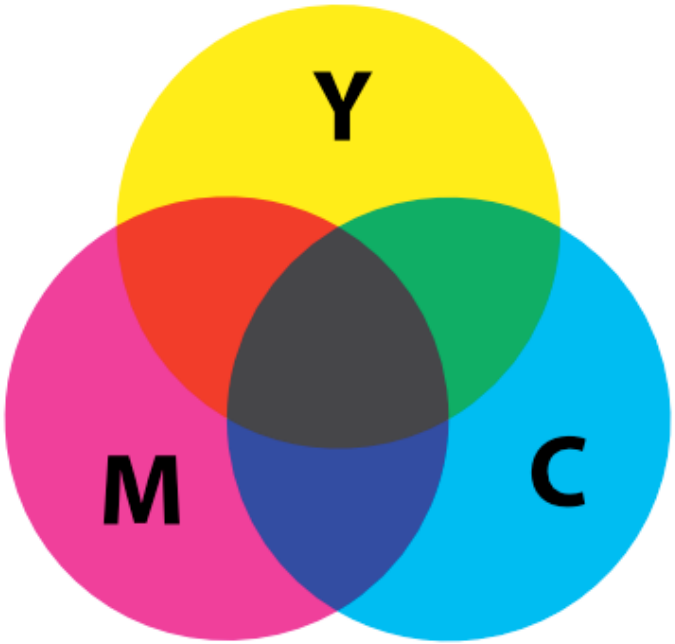
«Mittelgrau»

- lineare Funktion: etwa 18 %
- Potenzfunktion: 50 %
- Logarithmusfunktion: 50 %

Farbraum

- 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





$$\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{pmatrix} 1 & 0 & 1.396523 \\ 1 & -0.342793 & -0.711348 \\ 1 & 1.765078 & 0 \end{pmatrix} \begin{pmatrix} Y' \\ C_B \\ C_R \end{pmatrix}$$

$$\begin{pmatrix} Y' \\ C_B \\ C_R \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.168074 & -0.329965 & 0.498039 \\ 0.498039 & -0.417947 & -0.080992 \end{pmatrix} \begin{pmatrix} R' \\ G' \\ B' \end{pmatrix}$$

$$\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{pmatrix} 1 & 1 & -1 \\ 1 & 0 & 1 \\ 1 & -1 & -1 \end{pmatrix} \begin{pmatrix} Y' \\ C_O \\ C_G \end{pmatrix}$$

$$\begin{pmatrix} Y' \\ C_O \\ C_G \end{pmatrix} = \begin{pmatrix} \frac{1}{4} & \frac{1}{2} & \frac{1}{4} \\ \frac{1}{2} & 0 & -\frac{1}{2} \\ -\frac{1}{4} & \frac{1}{2} & -\frac{1}{4} \end{pmatrix} \begin{pmatrix} R' \\ G' \\ B' \end{pmatrix}$$

17

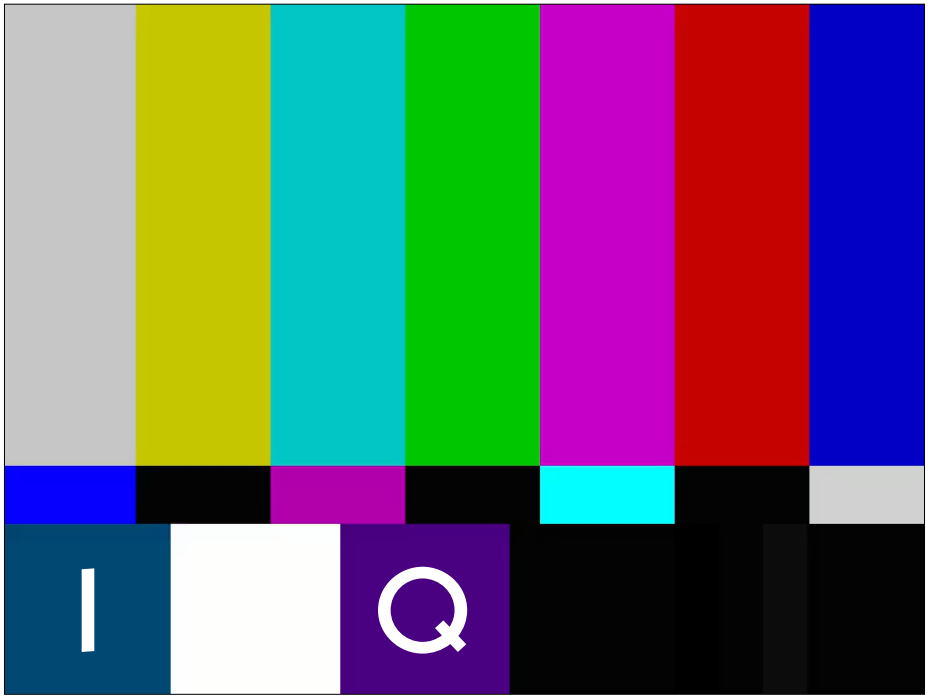
18

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

19



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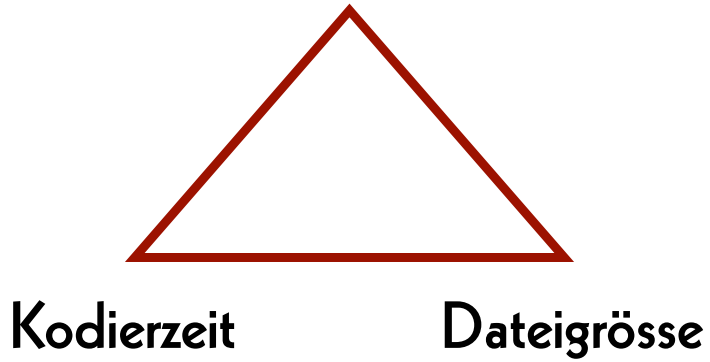


21

Kompression

- nicht komprimiert
- verlustfrei komprimiert
- verlustbehaftet komprimiert
- Farbunterabtastung
- komprimiert generiert

22

Nicht komprimiert

+ Daten sind leichter zu bearbeiten
+ Software läuft schneller
− grössere Dateien
− langsameres Schreiben, Übermitteln und Lesen der Dateien

Beispiele: TIFF, DPX, DNG, OpenEXR

23

Verlustfrei komprimiert

+ kleinere Dateien
+ schnelleres Schreiben, Übermitteln und Lesen der Dateien
− Daten sind komplexer zu bearbeiten
− Software läuft langsamer

Beispiele: JPEG 2000, FFV1

24

Verlustbehaftet komprimiert

- optimiert für Aufnahme und/oder Postproduktion
- optimiert für Zugang und Distribution

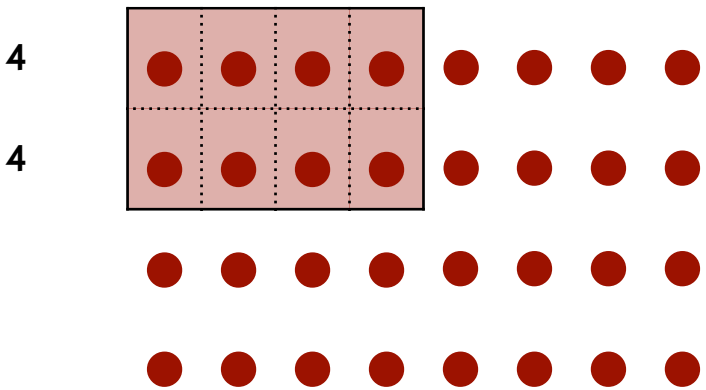
Beispiele (Mezzanine): ProRes 422, ProRes 4444; DNxHD, DNxHR

Beispiele (Zugang): H.264 (AVC), H.265 (HEVC), H.266 (VVC); AV1

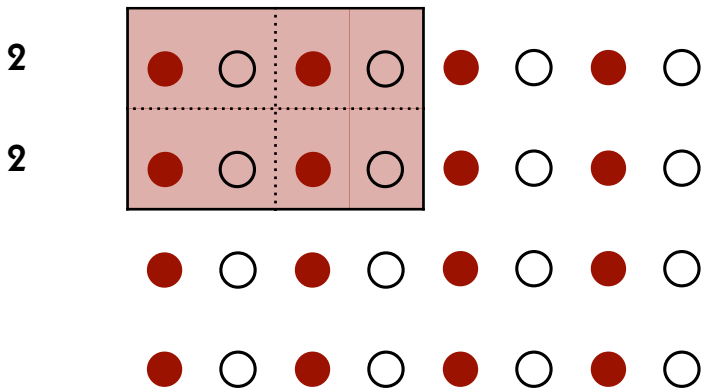
Farbunterabtastung

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

4:4:4



4:2:2



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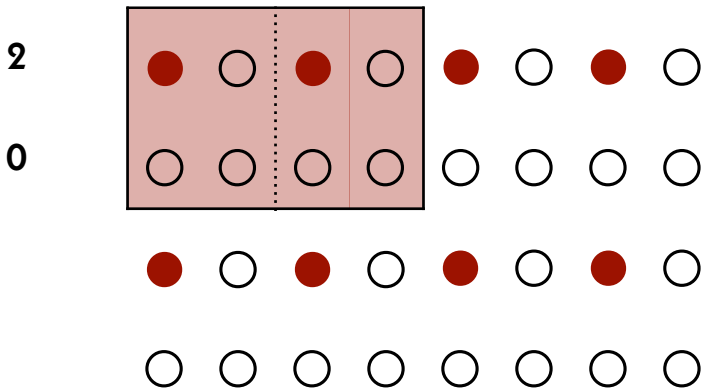


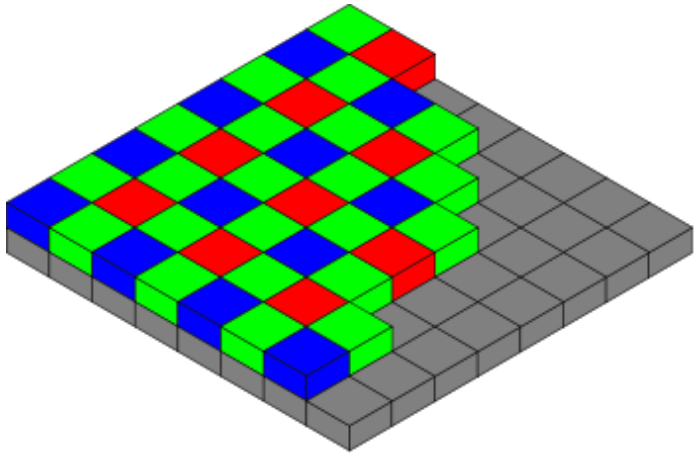
Komprimiert generiert

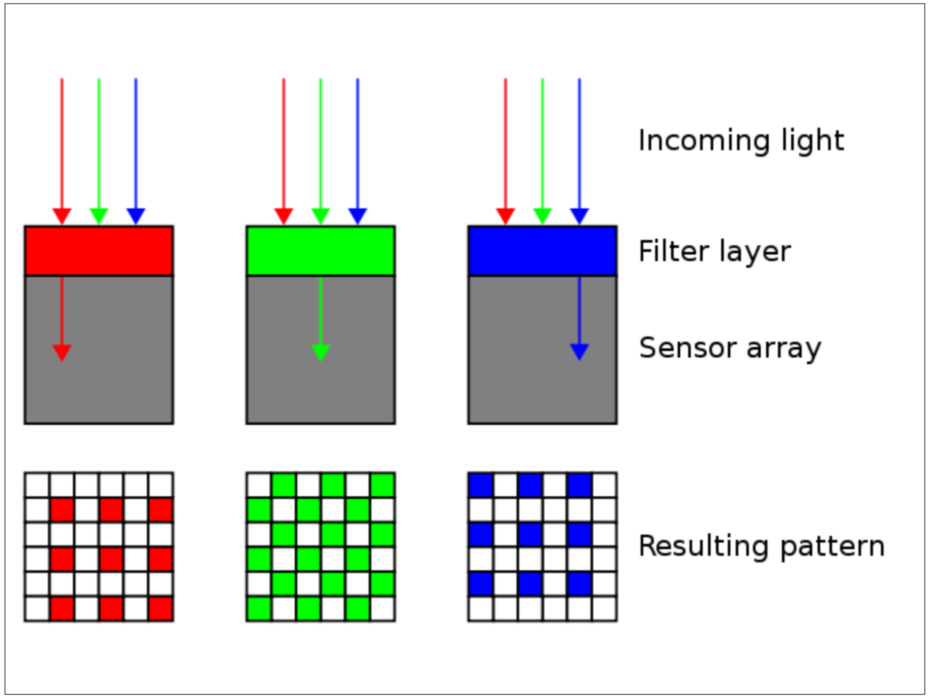
- sowohl für Aufnahme als auch für Postproduktion optimiert

Beispiele: CineForm RAW, ProRes RAW, Blackmagic RAW

Unbequeme Wahrheiten

- Sensoren sind farbenblind
- Bayer-Sensoren erzeugen kein vollständiges RGB-Bild





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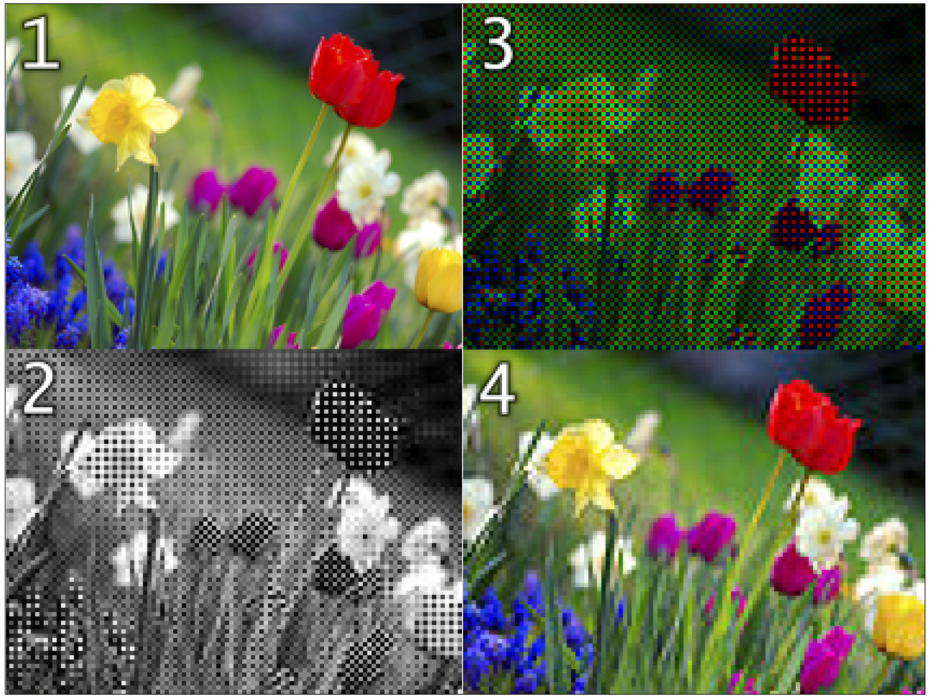

34

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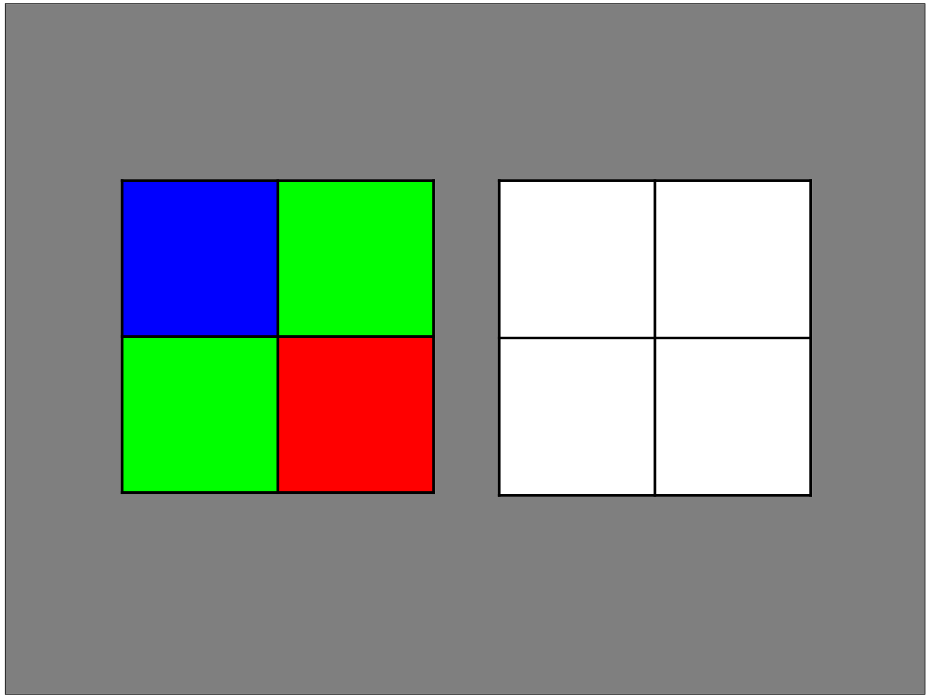
0100110101010101010100001011101010
0111010100101010100010110101011110
0001110101010101010100001011101010
0110101010010101010001011010101111
0010101010101010000101110101010000
0111010100101010100010110101011110
0101010101010101000010111010100110
1001011101010010101010001011010101
1110010101010101010100001011101010
0111010100101010100010110101011110
0101010101010101001101010100000001
0010100010101010101010010101010101
```

35



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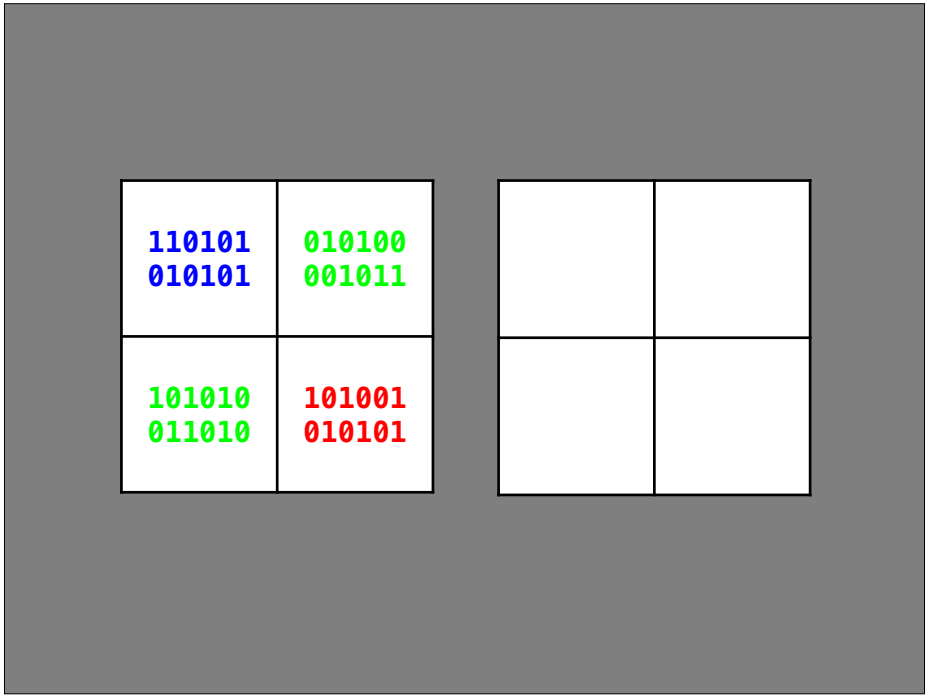
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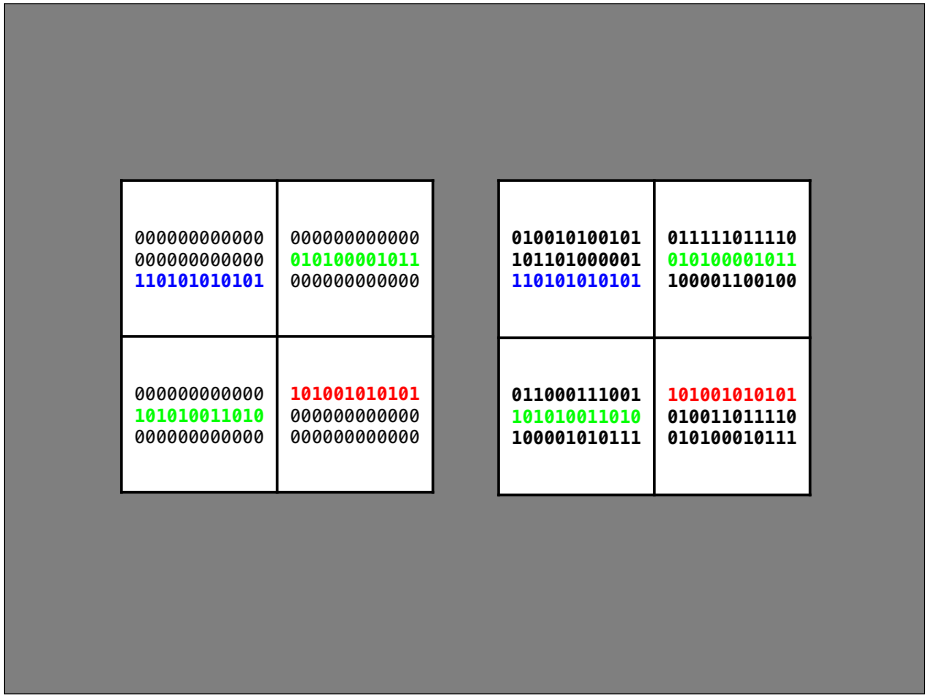
010101
010100
001011
101010
011010
101001
010101

37


000000000000
000000000000
110101010101
000000000000
010100001011
000000000000
000000000000
101001010101
000000000000
010010100101
101101000001
110101010101
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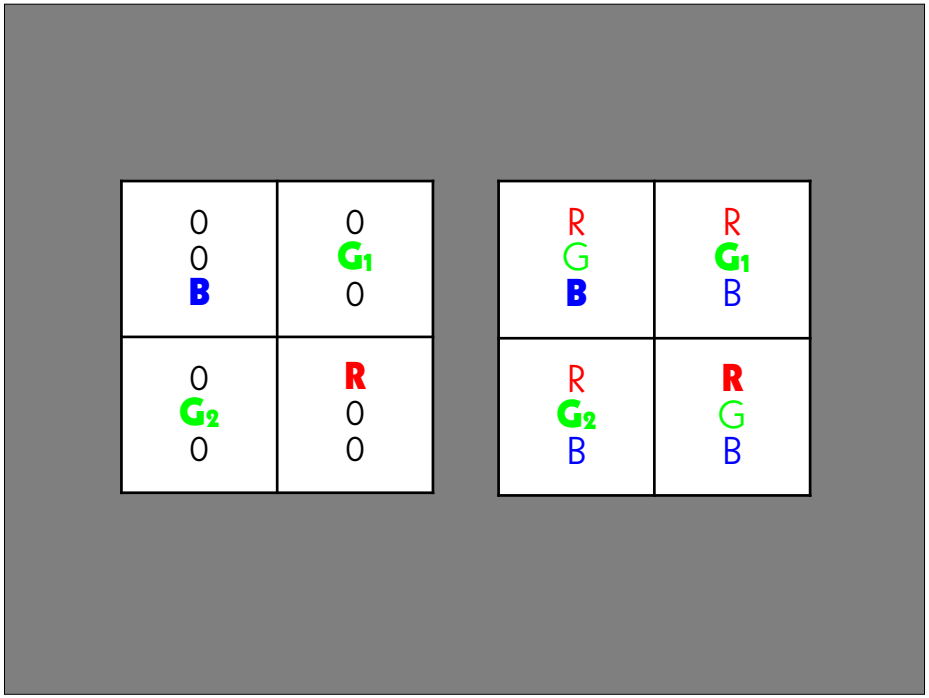
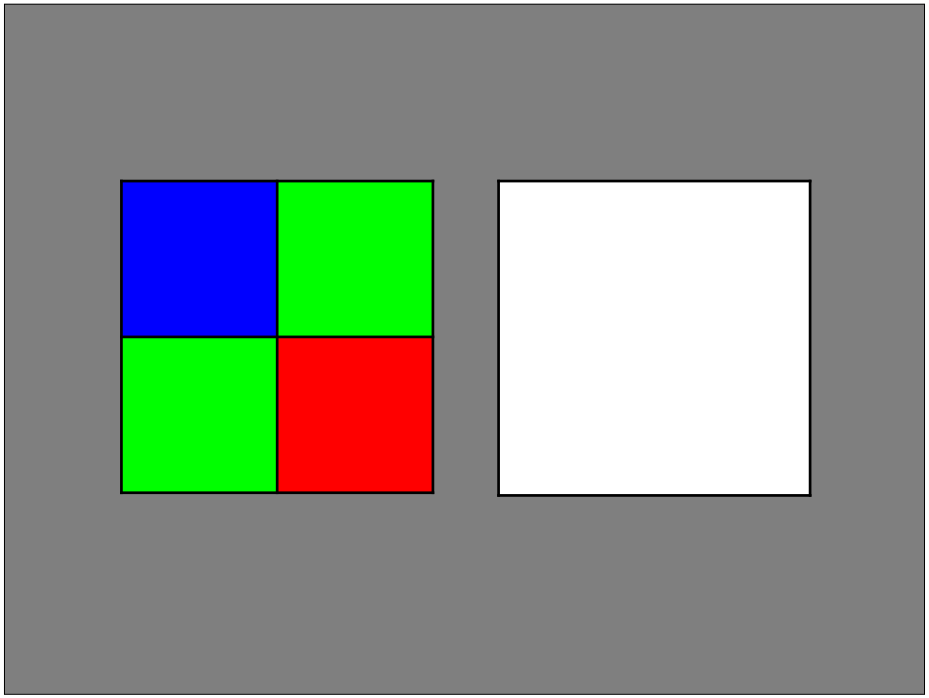
100001010111
101001010101
010011011110
010100010111

38


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

39



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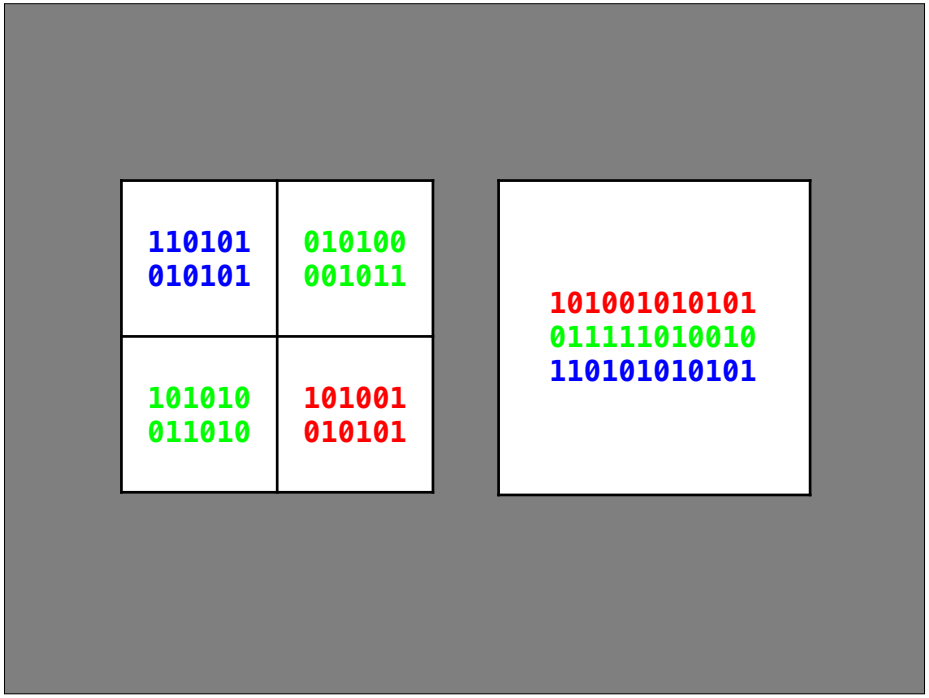
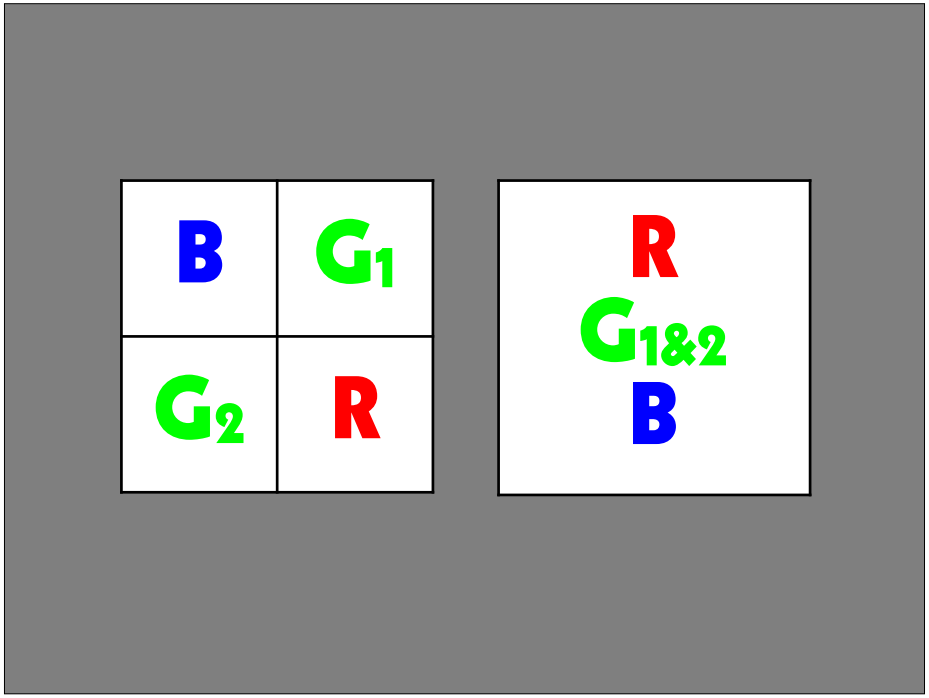




Zwei Möglichkeiten, Bayer-Daten zu speichern

digitales Aufblasen auf RGB

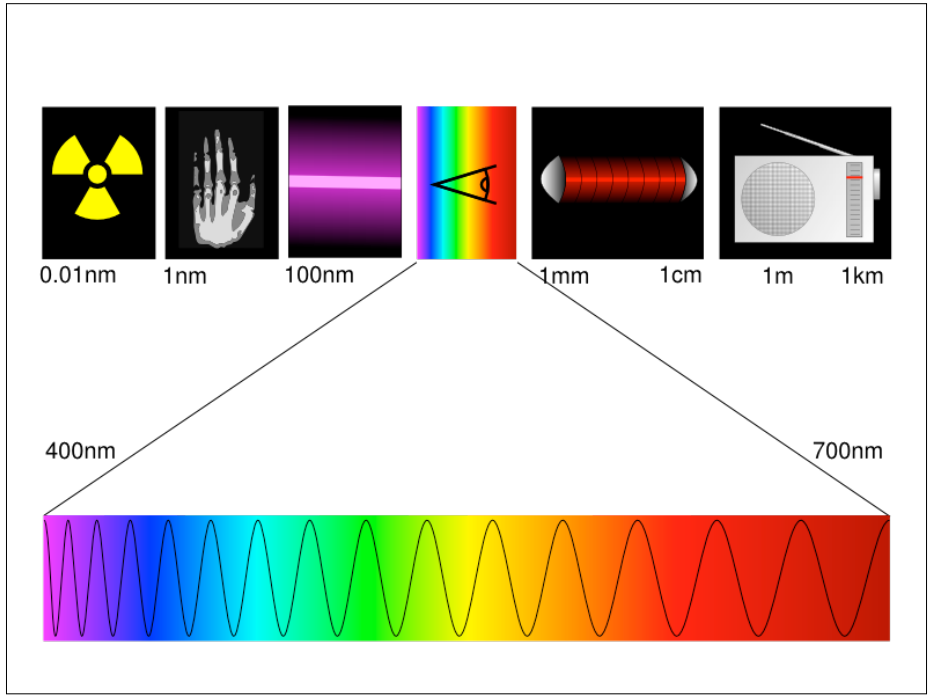
- die generierten Daten werden verdreifacht
- die Datei hat die volle Sensorauflösung
- nur die Hälfte der Daten ist real

digitale Reduktion auf RGB

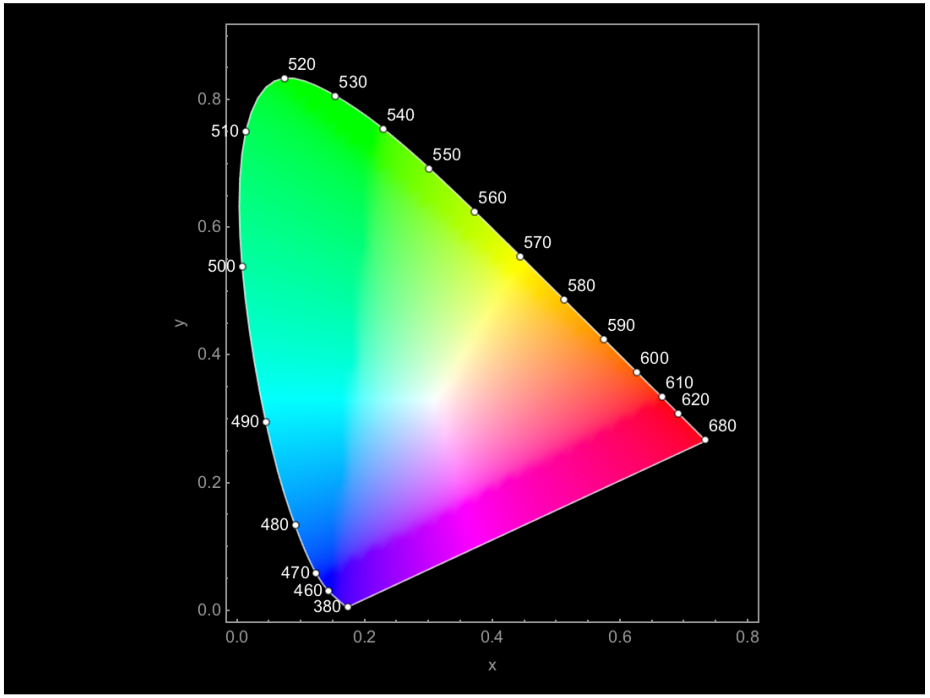
- drei Viertel der generierten Daten sind gespeichert
- die Datei hat die halbe Sensorauflösung
- die gesamten Daten sind real

Normlicht

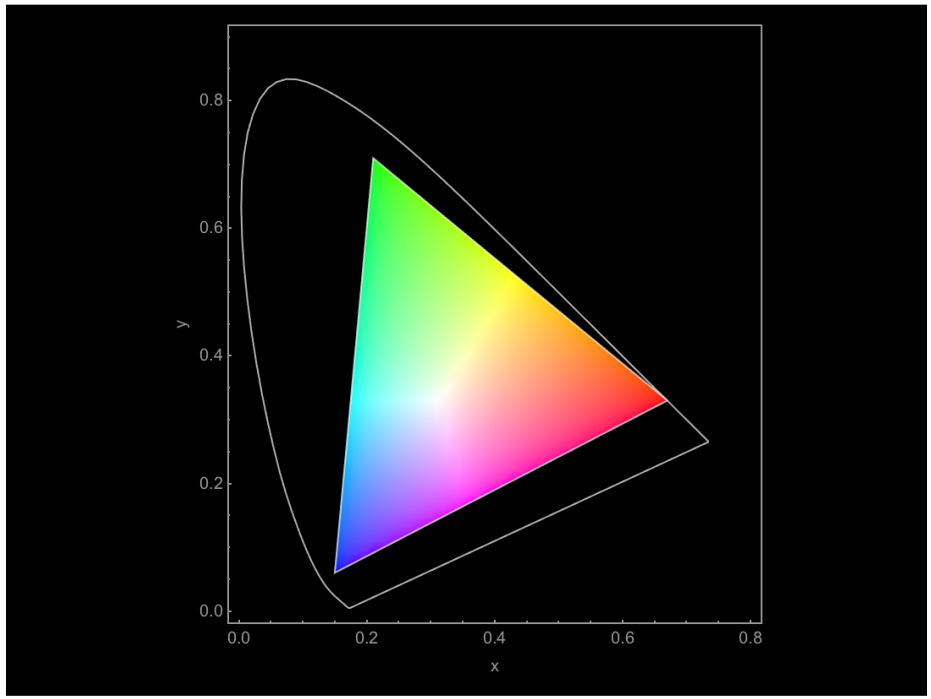
- D50
- D55
- D65
- D75


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

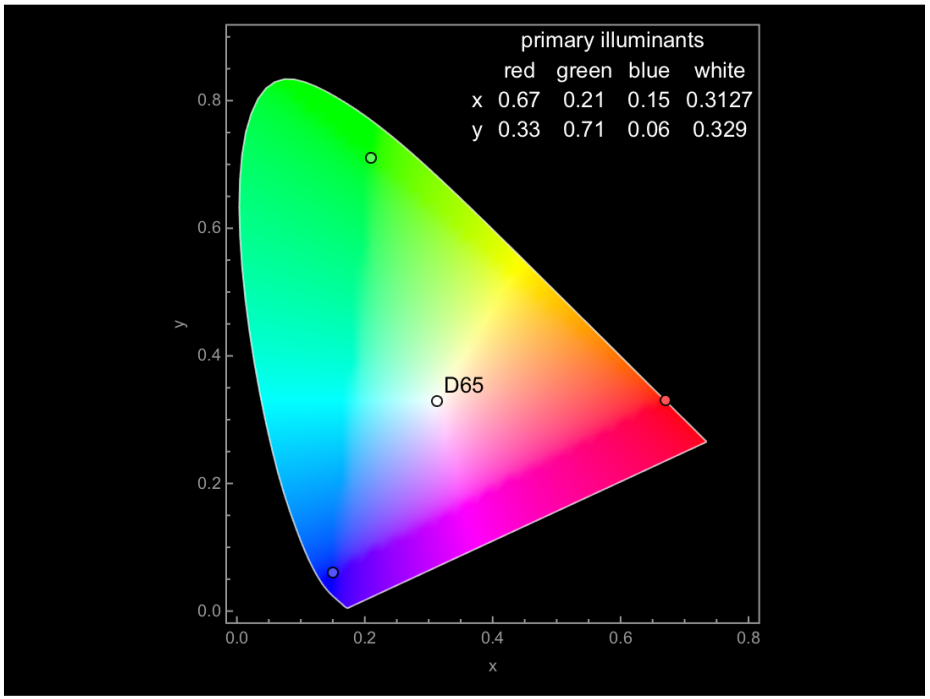
45


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

46


0.0
0.2
0.4
0.6
0.8
x
y

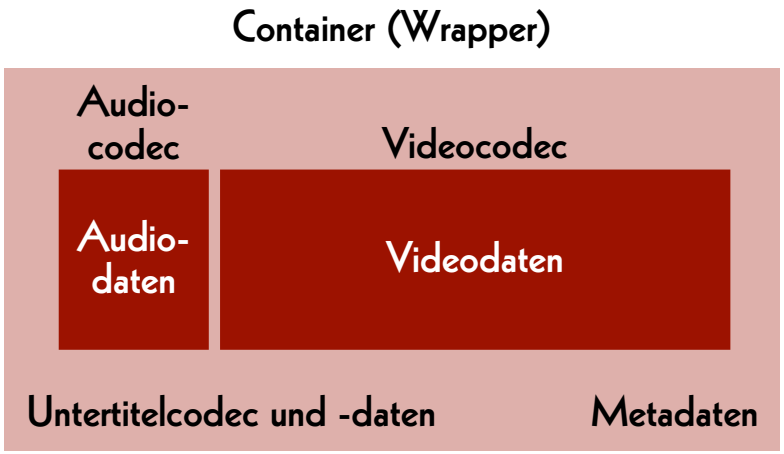
47


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

48

Dateiaufbau

Dateiaufbau



Container für Datenfluss

- MP4
- QuickTime (.mov)
- AVI
- Flash
- MXF
- Matroska (.mkv)

Container für Einzelbilder

- Ordner
- TAR
- ZIP
- MXF
- Matroska (.mkv)
- CinemaDNG
- Motion JPEG

Audiocodec

- WAVE
- BWF
- AAC
- MP3
- FLAC

Videocodec (Master)

Einzelbilder

- TIFF
- DPX
- JPEG 2000
- OpenEXR
- DNG

Datenfluss

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

Videocodec (Mezzanine)

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

Videocodec (Zugang)

- H.264 (AVC)
- H.265 (HEVC)
- H.266 (VVC)
- AV1

Data is anything but «raw».

Audiodaten

- pcm_s16le
- pcm_s24le
- pcm_s32le

Videodaten

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

Dateiformate

Grundsätze

- **Ein Archiv muss seine Dateien pflegen und handhaben können.**
- Open Source
- einfache Bedienung und ausführliche Dokumentation
- weite Verbreitung

Formate für verschiedene Anwendungszwecke

Archivmasterformat
→ zur Erhaltung und Archivierung

Mezzanine-Format
→ zur Bearbeitung und Postproduktion

Distributionsformat
→ zur Verbreitung und Zugänglichmachung

Elena Rossi-Snook:

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

Archivmaster (heute)

«Film» (Einzelbilder)
- Ordner, TIFF, 2K oder 4K, RGB, 16 bit
- MXF, DPX, 2K oder 4K, R'G'B', 10 bit

«Video» (Datenfluss)
- AVI, «raw», HD, $Y'C_BC_R$ 4:2:2, 10 bit
- Matroska, FFV1, HD, $Y'C_BC_R$ 4:2:2, 10 bit

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

Mezzanine (heute)

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

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

Zugang (heute)

MP4

Bild
- H.264, SD, $Y'C_BC_R$ 4:2:0, 8 bit, lossy
- H.264, «HD», $Y'C_BC_R$ 4:2:0, 8 bit, lossy

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

Archivmaster und Mezzanine

«Film» (Einzelbilder)
- Matroska, FFV1, 4K oder 2K, RGB, 16 bit

«Video» (Datenfluss)
- Matroska, FFV1, «HD», $Y'C_BC_R$ 4:2:2, 10 bit

Ton
- Matroska, FLAC, 192 kHz, 24 bit

Zugang

MP4

Bild
- H.265, «HD», $Y'C_BC_R$ 4:2:0, 8 bit, lossy
- H.266, «HD», $Y'C_BC_R$ 4:2:0, 8 bit, lossy
- AV1, «HD», $Y'C_BC_R$ 4:2:0, 8 bit, lossy

Ton
- AAC, 96 kHz, 16 bit

Bibliografie

Reto Kromer: **Matroska and FFV1: One File Format for Film and Video Archiving?**, in «Journal of Film Preservation», Nr. 96 (April 2017), FIAF, Brüssel, Belgien, S. 41–45

➔ https://retokromer.ch/publications/JFP_96.html

Vor- und Nachteile

Container:

- Ordner
- TAR
- ZIP
- MXF
- Matroska

Codec:

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

	Vorteile	**Nachteile**
TIFF DPX OpenEXR	Daten leichter zu bearbeiten	grössere Dateien
JPEG 2000 FFV1	kleinere Dateien	Daten komplexer zu bearbeiten

MXF-Container (.mxf)

Videocodec

- DPX
- JPEG 2000
- DNxHD, DNxHR
- ProRes 422, ProRes 4444

SMPTE REGISTERED DISCLOSURE DOCUMENT

MXF Archive and Preservation Format Registered Disclosure Document

The attached document is a Registered Disclosure Document prepared by the sponsor identified below. It has been examined by the appropriate SMPTE Technology Committee and is believed to contain adequate information to satisfy the objectives defined in the Scope, and to be technically consistent.

This document is NOT a Standard, Recommended Practice or Engineering Guideline, and does NOT imply a finding or representation of the Society.

Every attempt has been made to ensure that the information contained in this document is accurate. Errors in this document should be reported to the proponent identified below, with a copy to eng@smpte.org.

All other inquiries in respect of this document, including inquiries as to intellectual property requirements that may be attached to use of the disclosed technology, should be addressed to the proponent identified below.

Proponent Contact Information:
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101 Independence Ave, S.E.
Washington, DC 20540-1300

Email: kmur@loc.gov

MXF / DPX

MXF

➔ SMPTE RDD 48:2018

DPX

➔ SMPTE ST 268M:2015

MXF / JPEG 2000

MXF

➔ SMPTE RDD 48:2018

JPEG 2000

➔ ISO/IEC 15444-1:2019

➔ **usw.**

MXF / DNx

MXF

➔ SMPTE RDD 48:2018

DNxHD, DNxHR

➔ nicht veröffentlicht

MXF / ProRes

MXF

➔ SMPTE RDD 48:2018

ProRes 422, ProRes 4444

➔ SMPTE RDD 36:2015

SMPTE RDD 36:2015

SMPTE REGISTERED DISCLOSURE DOCUMENT

Apple ProRes Bitstream Syntax and Decoding Process

Page 1 of 39 pages

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All other inquiries in respect of this document, including inquiries as to intellectual property requirements that may be attached to use of the disclosed technology, should be addressed to the proponent identified below.

Proponent contact information:

ProRes Program Office
Apple Inc.
1 Infinite Loop, MS: 77-2YAK
Cupertino, CA 95014
USA

Email: ProRes@apple.com

Matroska-Container (.mkv)

Videocodec

- FFV1
- ProRes 422, ProRes 4444

Matroska / FFV1

Matroska (.mkv)

➔ IETF Internet Draft

FFV1

➔ IETF RFC 9043

Stream: Internet Engineering Task Force (IETF)
RFC: 9043
Category: Informational
Published: August 2021
ISSN: 2070-1721
Authors: M. Niedermayer D. Rice J. Martinez

RFC 9043
FFV1 Video Coding Format Versions 0, 1, and 3

Abstract

This document defines FFV1, a lossless, intra-frame video encoding format. FFV1 is designed to efficiently compress video data in a variety of pixel formats. Compared to uncompressed video, FFV1 offers storage compression, frame fixity, and self-description, which makes FFV1 useful as a preservation or intermediate video format.

Status of This Memo

This document is not an Internet Standards Track specification; it is published for informational purposes.

This document is a product of the Internet Engineering Task Force (IETF). It represents the consensus of the IETF community. It has received public review and has been approved for publication by the Internet Engineering Steering Group (IESG). Not all documents approved by the IESG are candidates for any level of Internet Standard; see Section 2 of RFC 7841.

Information about the current status of this document, any errata, and how to provide feedback on it may be obtained at https://www.rfc-editor.org/info/rfc9043.

Matroska / ProRes

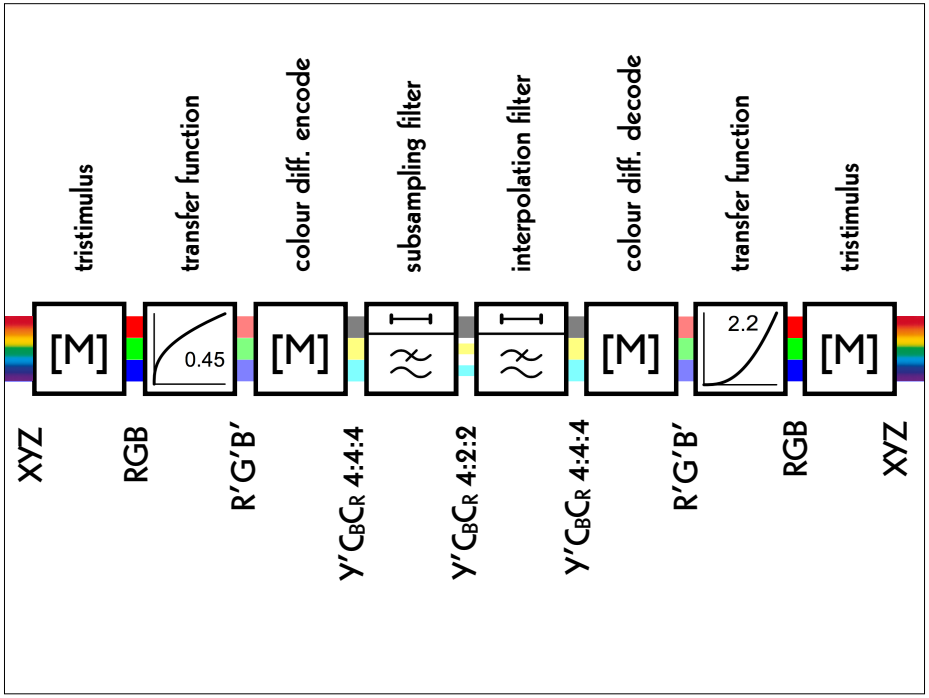
Matroska (.mkv)

➔ IETF Internet Draft

ProRes 422, ProRes 4444

➔ SMPTE RDD 36:2015

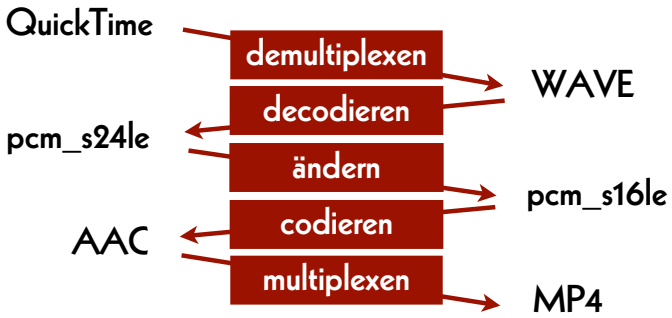
Umwandlungen



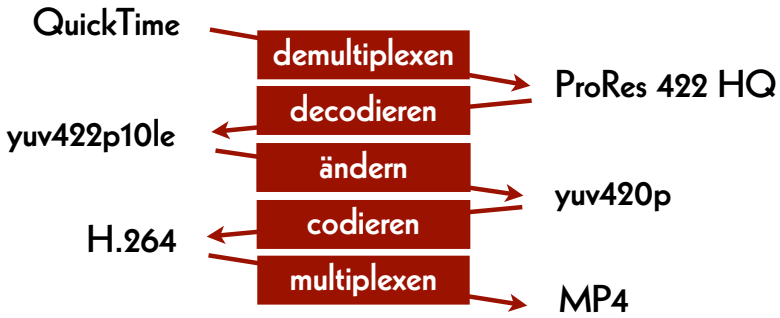
Dateiumwandlungen

- demultiplexen
- decodieren
- ändern
- codieren
- multiplexen

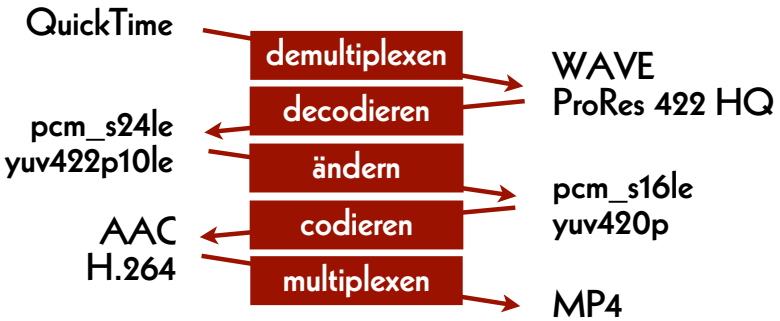
Beispiel: Ton



Beispiel: Bild



Beispiel: Bild und Ton



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