

Audiovisuelle Dateiformate

Reto Kromer • AV Preservation by reto.ch

Memoriav-Workshop
Open Source im Archivalltag
Bern, 10. Januar 2024

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Digitaler Ton

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Inhalt

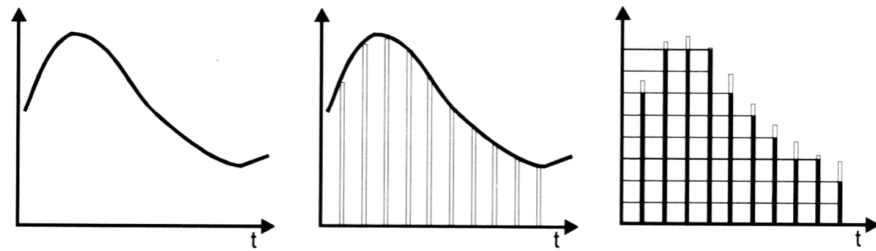
- digitaler Ton und digitales Bild
- Container, Codec, Rohdaten
- verschiedene Formate für unterschiedliche Zwecke
- audiovisuelle Dateiumwandlungen
- Datensicherung und Migration

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Digitaler Ton

- Abtastung
- Quantisierung
- Kompression

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Digitalisierung = Abtastung + Quantisierung

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Abtastung

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

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Quantisierung

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

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Digitales Bild

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Digitales Bild

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

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Auflösung

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

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

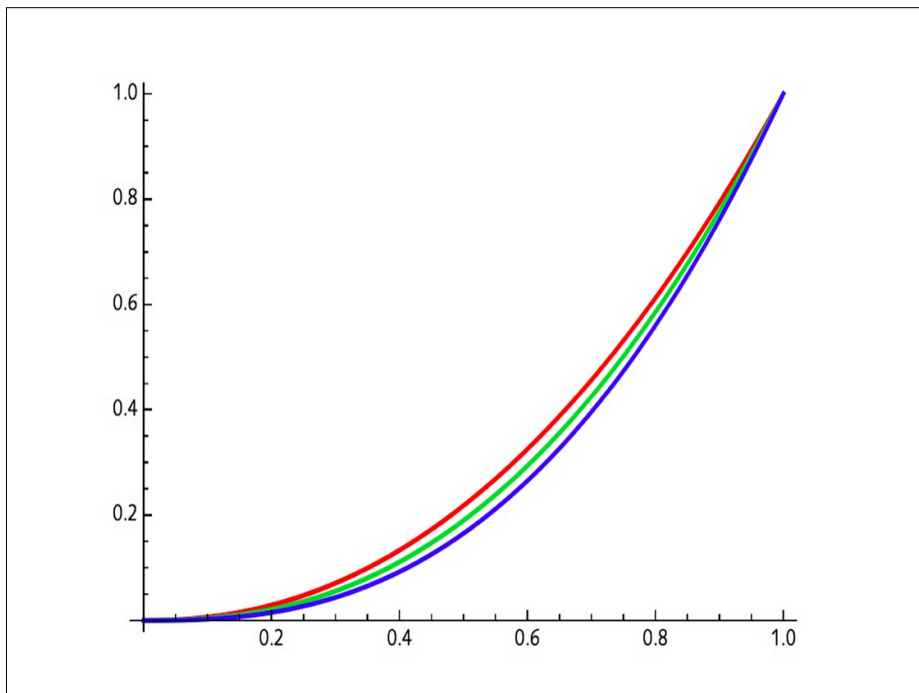
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Linear, Potenz, Logarithmus

«Mittelgrau»

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

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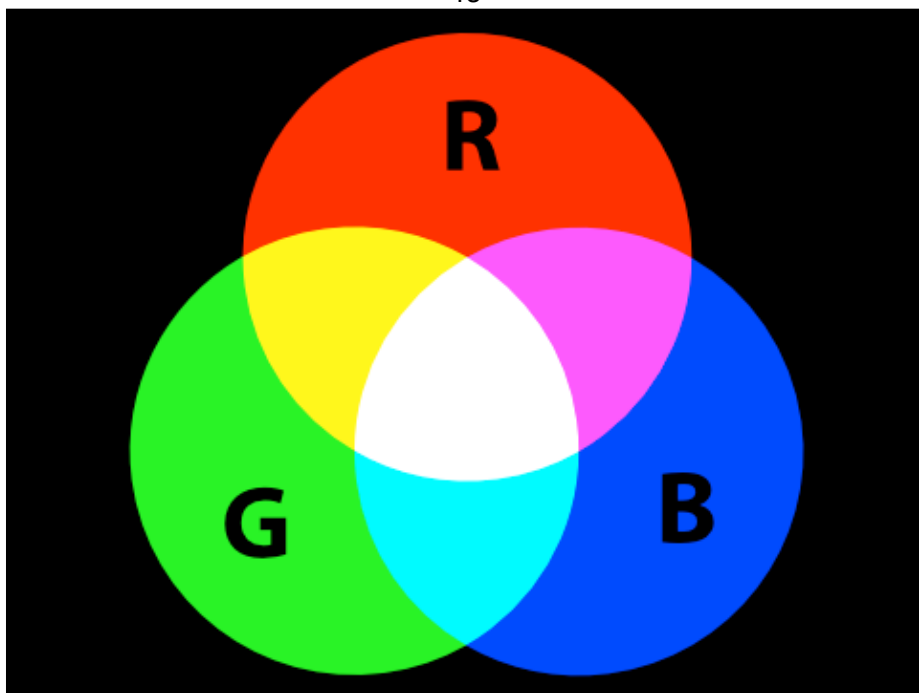


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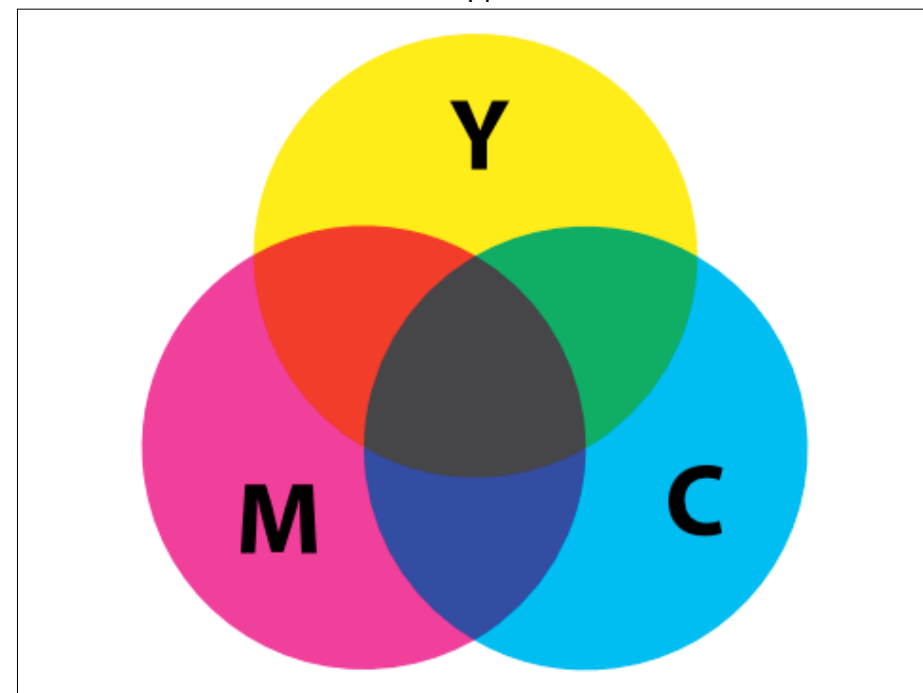
Farbraum

- XYZ, $L^*a^*b^*$
- RGB / $R'G'B'$ / CMY / $C'M'Y'$
- $Y'IQ$ / $Y'UV$ / $Y'D_BD_R$
- $Y'C_BC_R$ / $Y'CoC_G$
- $Y'P_BP_R$

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

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

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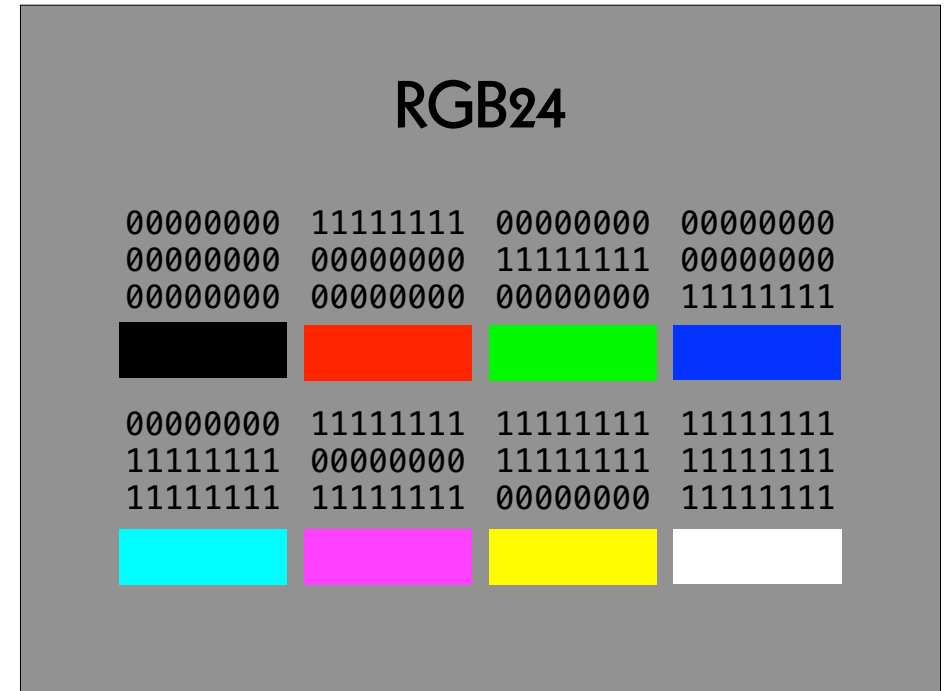


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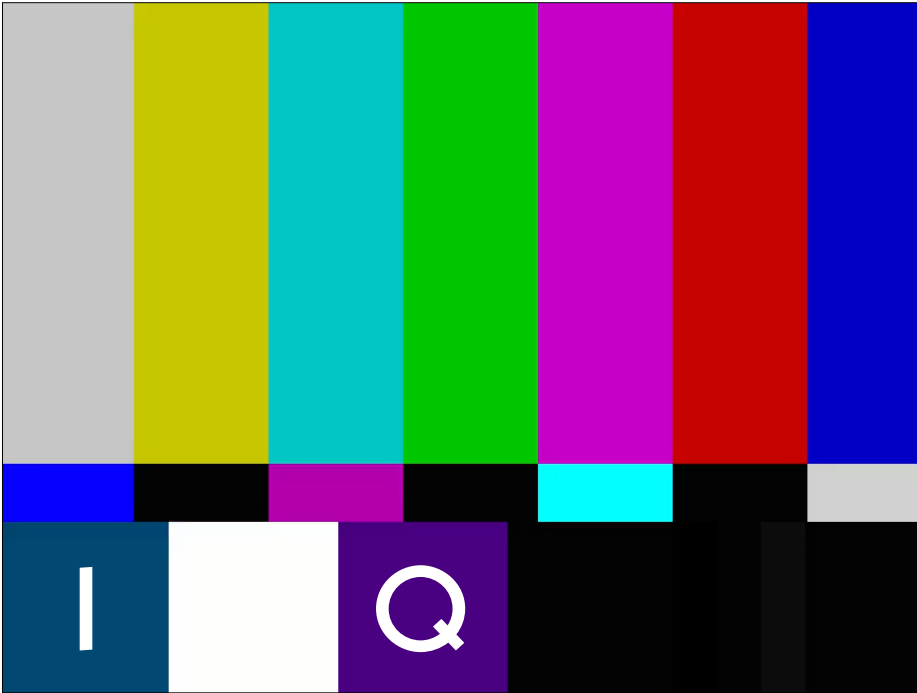
$$\begin{pmatrix} R' \\ G' \\ B' \end{pmatrix} = \begin{pmatrix} 1 & 1 & -1 \\ 1 & 0 & 1 \\ 1 & -1 & -1 \end{pmatrix} \begin{pmatrix} Y' \\ C_O \\ C_G \end{pmatrix}$$

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

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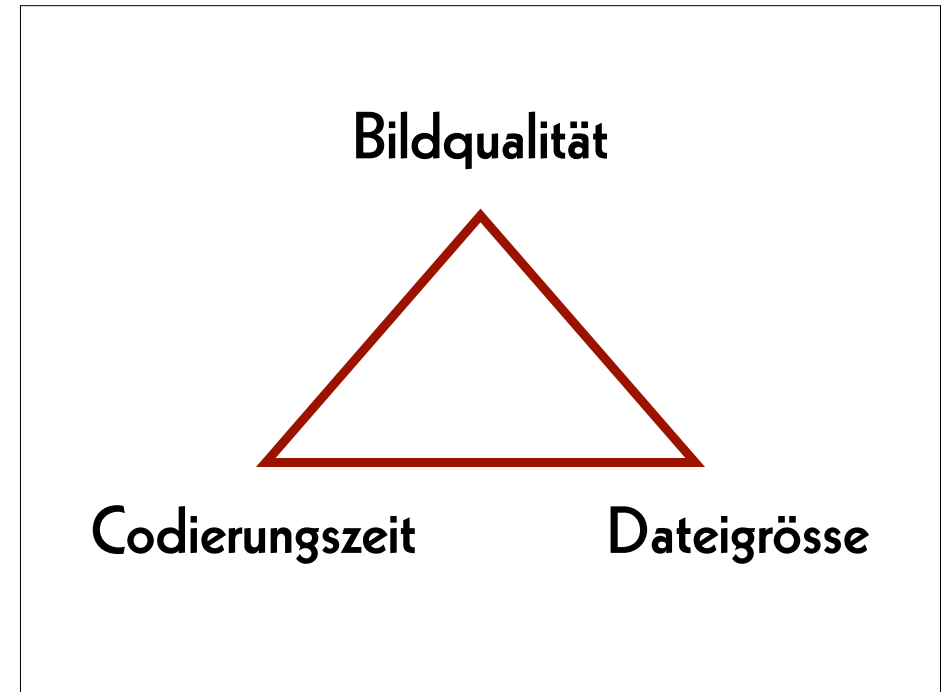


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Kompression

- nicht komprimiert
- verlustfrei komprimiert
- verlustbehaftet komprimiert
- Farunterabtastung
- komprimiert generiert

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Nicht komprimiert

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

Beispiele: TIFF, DPX, DNG, OpenEXR

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Verlustfrei komprimiert

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

Beispiele: JPEG 2000, FFV1

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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

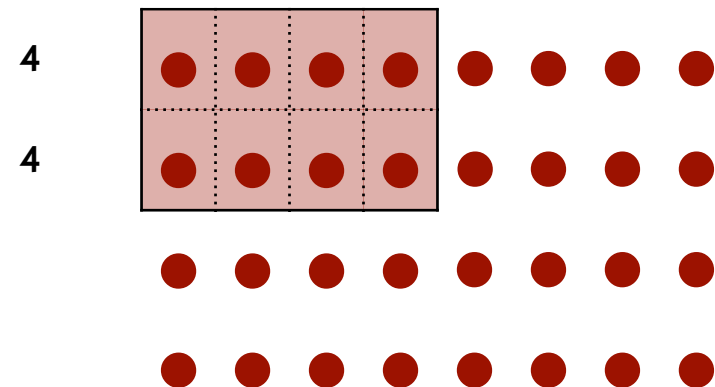
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Farbunterabtastung

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

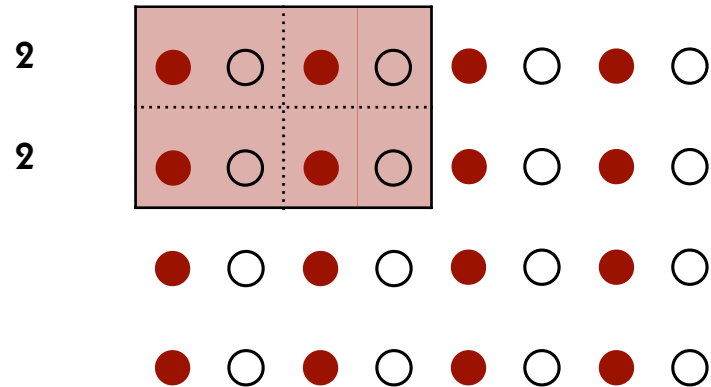
27

4:4:4



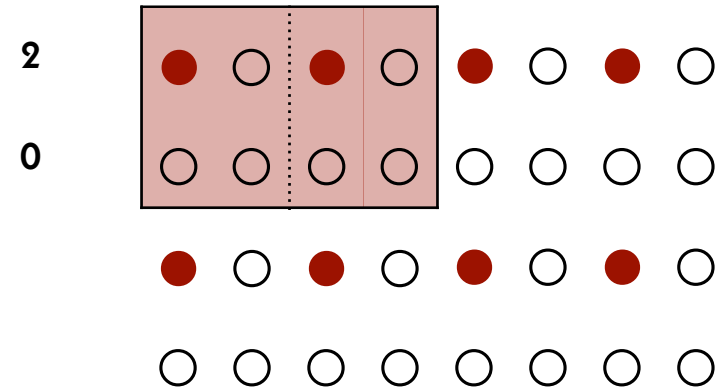
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4:2:2



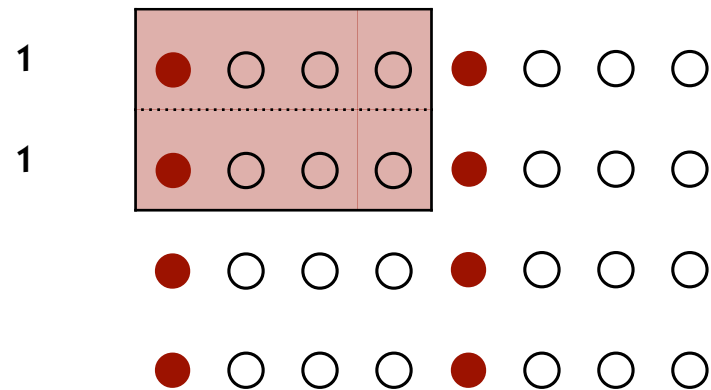
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4:2:0



30

4:1:1



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Komprimiert generiert

- sowohl für Aufnahme als auch für Postproduktion optimiert

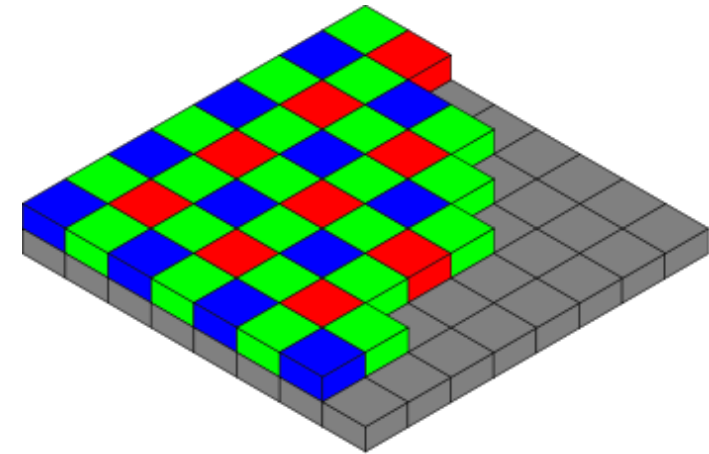
Beispiele: CineForm RAW, ProRes RAW, Blackmagic RAW

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Unbequeme Tatsachen

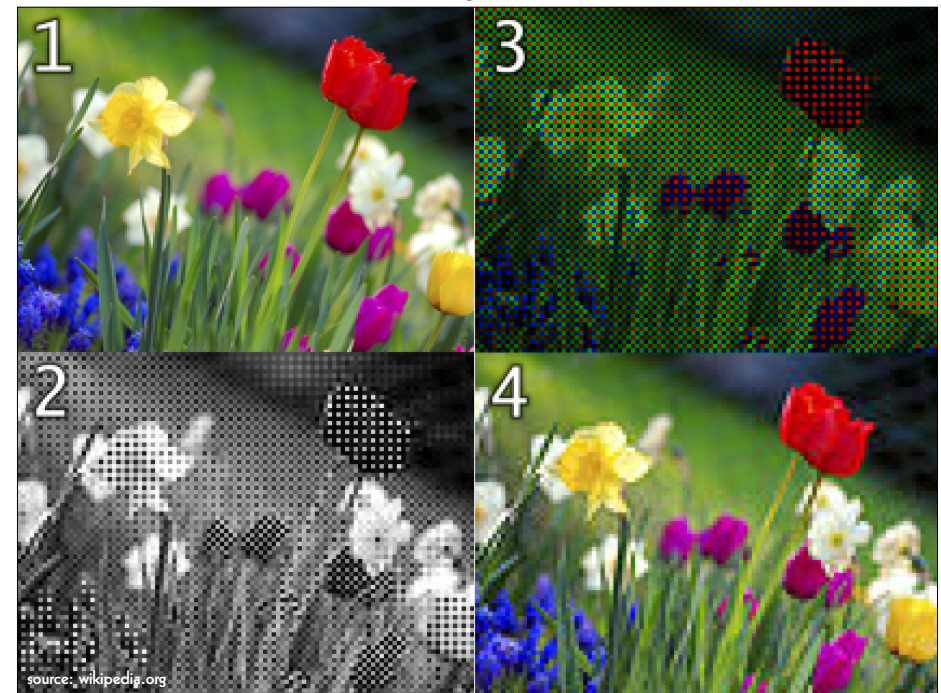
- Sensoren sind farbenblind
- Bayer-Sensoren erzeugen kein vollständiges RGB-Bild

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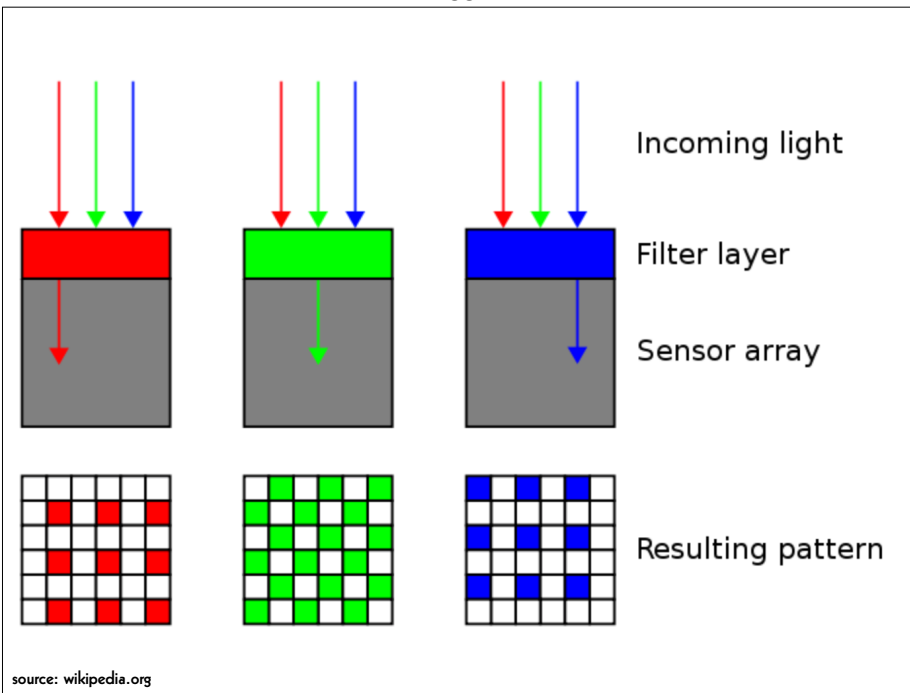
source: wikipedia.org

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source: wikipedia.org

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source: wikipedia.org

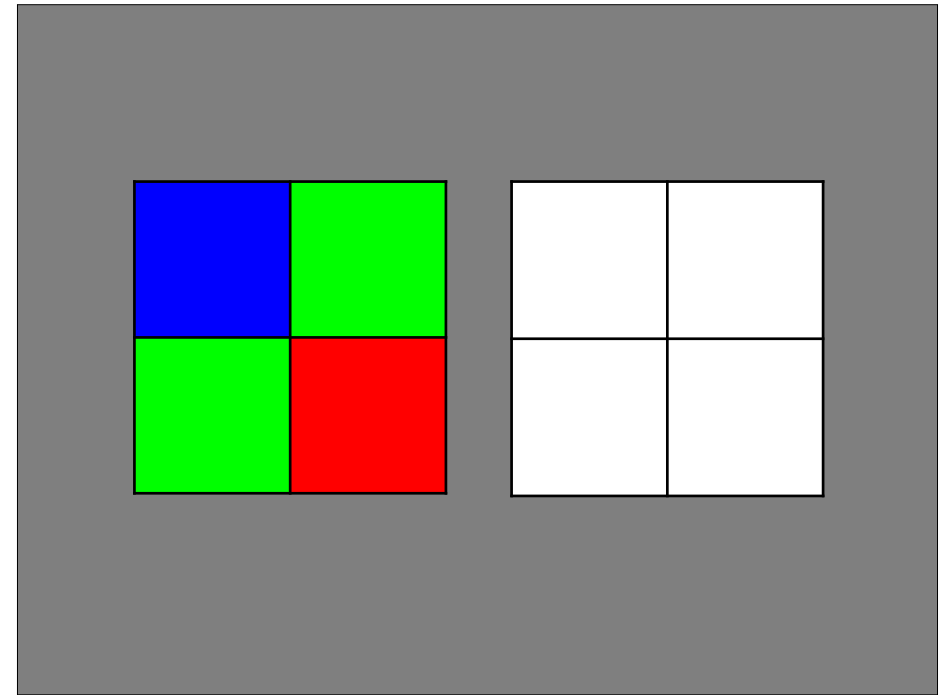
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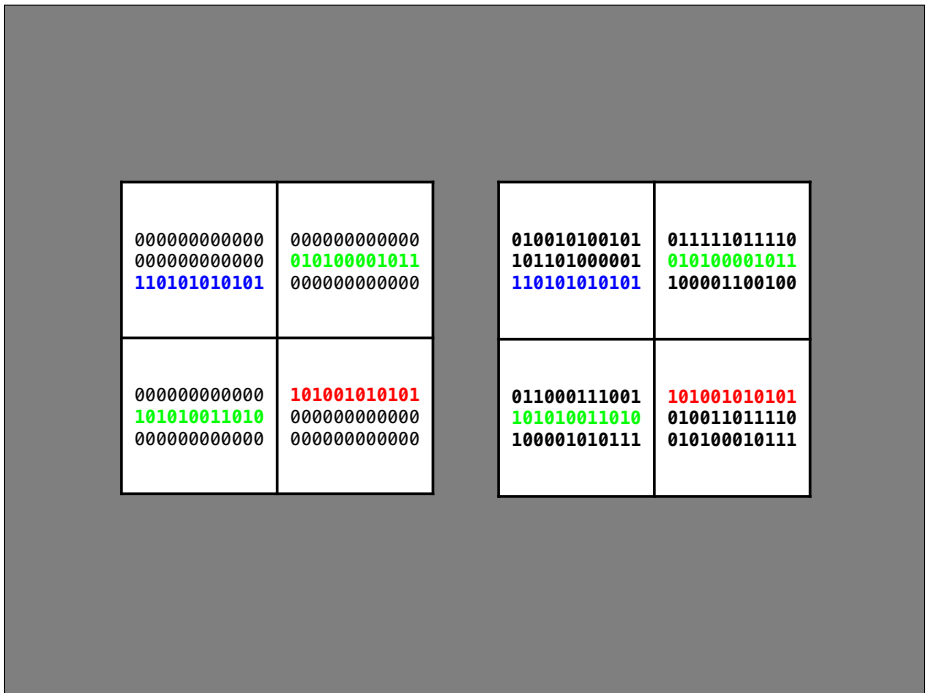
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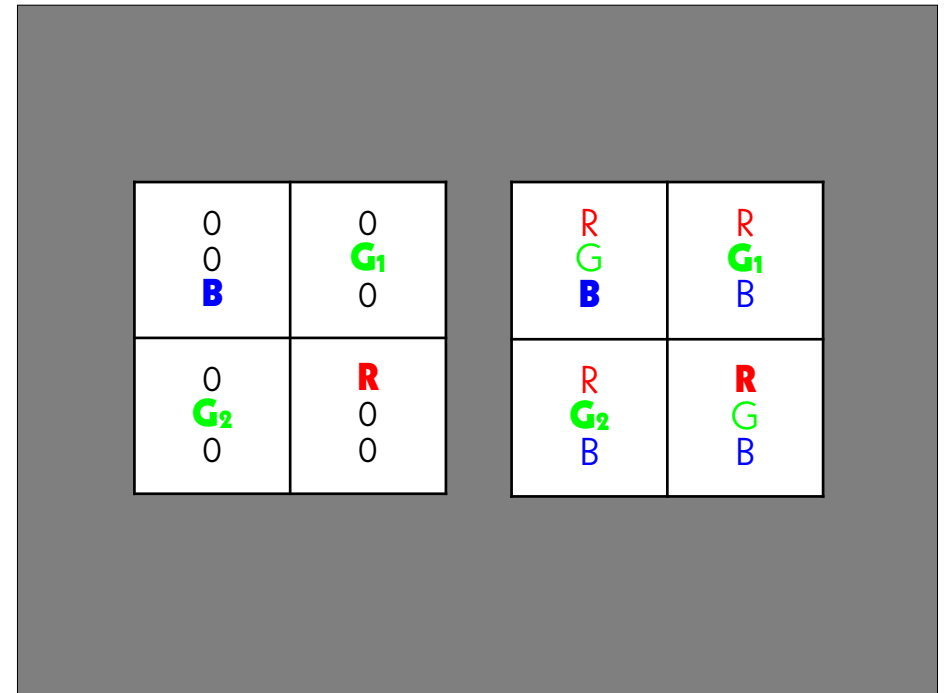
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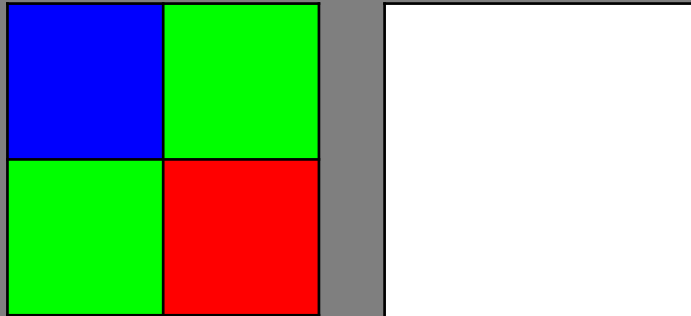
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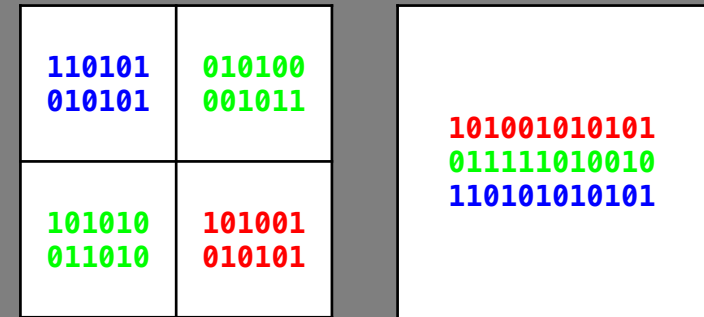
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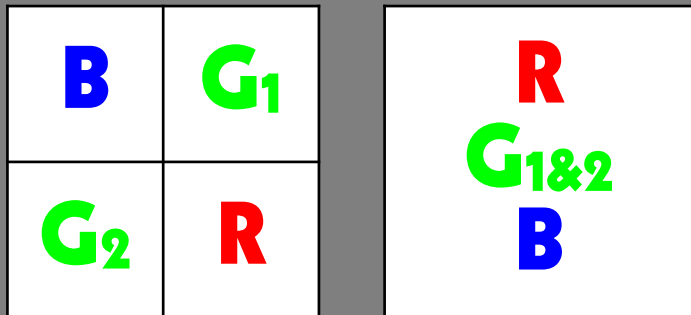
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Bayer-Daten benützen

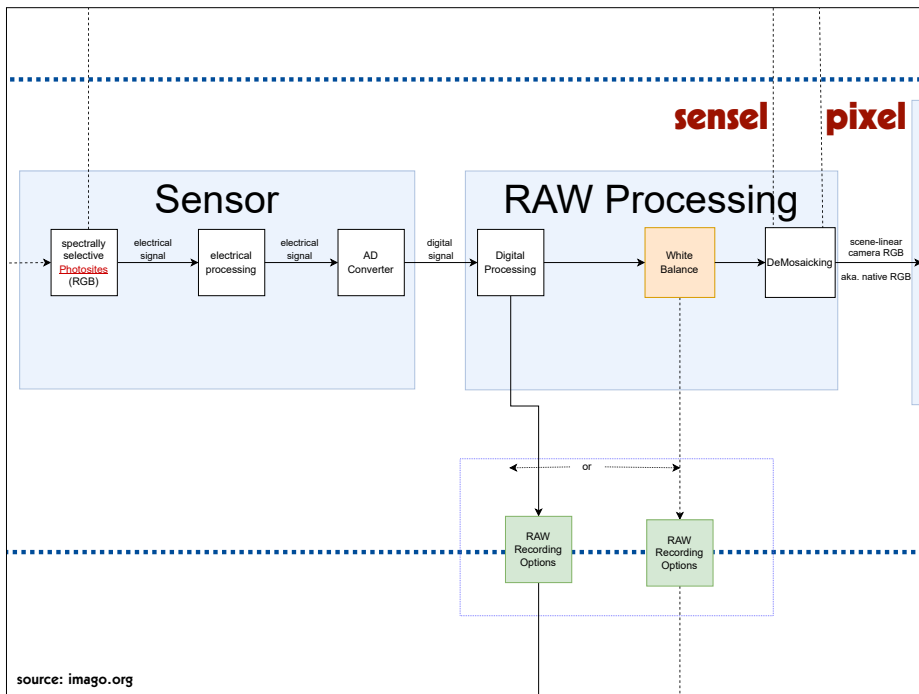
digitales Aufblasen auf RGB

- 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

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Normlicht

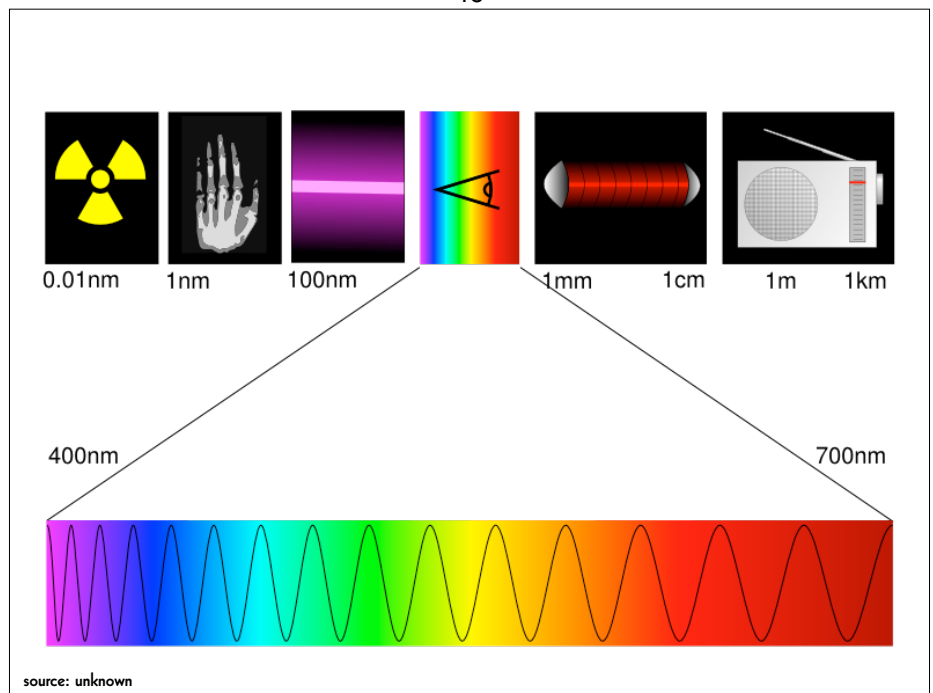
- D50
- D55
- D65
- D75

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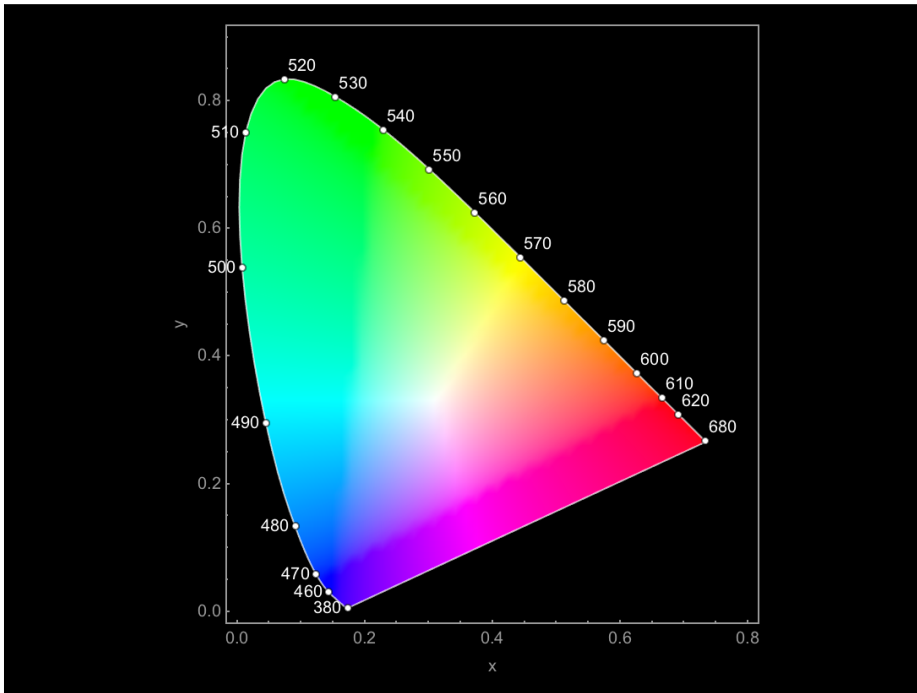
Bayer-Daten speichern

- pixel values generated by one de-mosaicking algorithm (digital blow-up)
- pixel values generated by mixing two green sensel values into one (digital reduction)
- raw sensel values

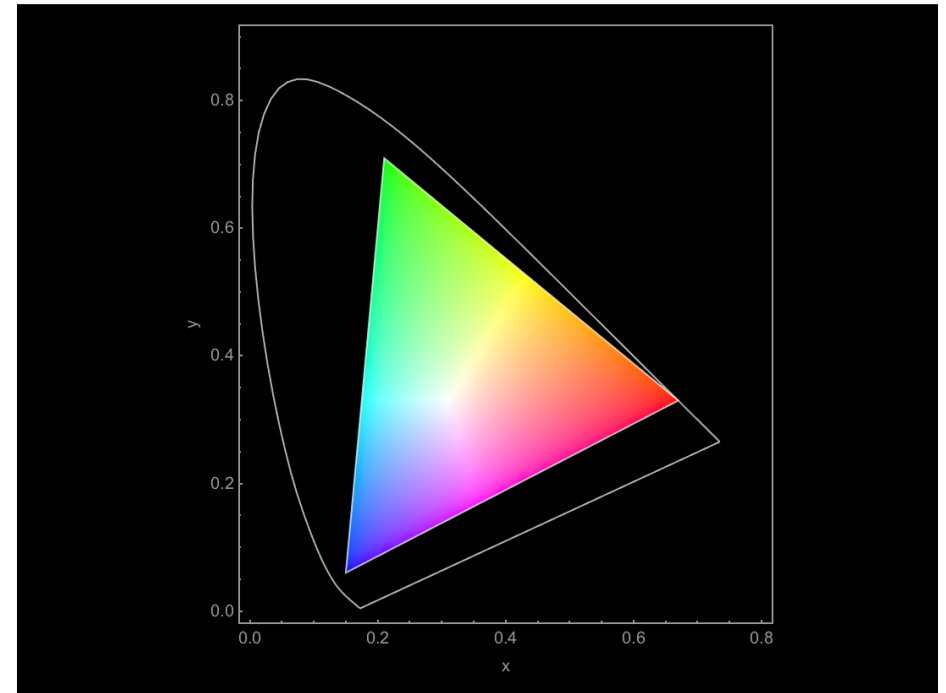
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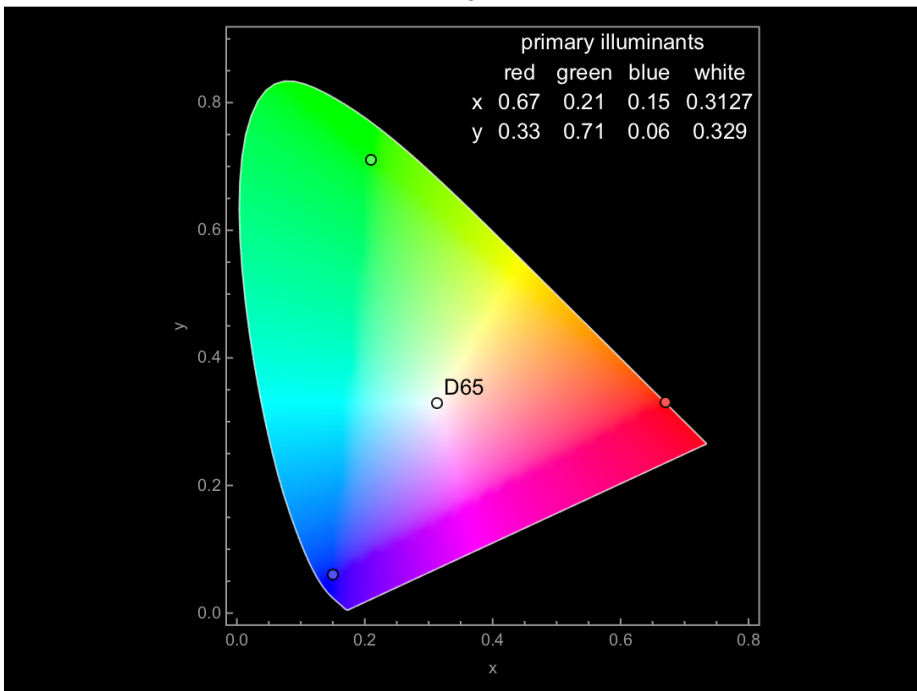
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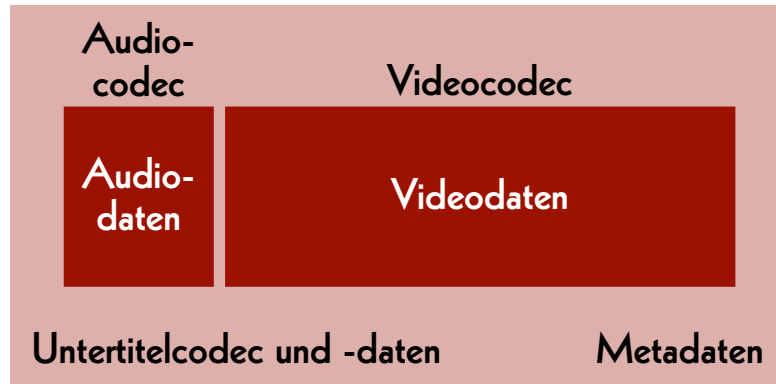
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Dateiaufbau

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Dateiaufbau

Container (Wrapper)



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Container für Datenfluss

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

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Container für Einzelbilder

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

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Audiocodec

- WAVE
- BWF
- AAC
- MP3
- FLAC

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Videocodec (Master)

Einzelbilder

- TIFF
- DPX
- JPEG 2000
- OpenEXR
- DNG

Datenfluss

- $Y'CbCr$ 8 bit
- $Y'CbCr$ 10 bit
- HuffYUV
- FFV1

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Videocodec (Mezzanine)

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

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Videocodec (Zugang)

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

- AV1

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RAW data are cooked.

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Audiodaten

- pcm_s16le
- pcm_s24le
- pcm_s32le

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Videodaten

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

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What is inside my DPX?

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

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Dateiformate

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Grundsätze

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

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Formate für verschiedene Anwendungszwecke

Archivmasterformat

→ zur Erhaltung und Archivierung

Mezzanine-Format

→ zur Bearbeitung und Postproduktion

Distributionsformat

→ zur Verbreitung und Zugänglichmachung

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Elena Rossi-Snook:

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

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Archivmaster (heute)

Einzelbilder («Film»)

- Ordner, TIFF, 2K oder 4K, RGB, 16 bit
- MXF, DPX, 2K oder 4K, R'G'B', 10 bit

Datenfluss («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

Ton

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

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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

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Archivmaster und Mezzanine

Einzelbilder («Film»)

- Matroska, FFV1, 4K oder 2K, RGB, 16 bit
- Matroska, FFV1, 4K oder 2K, R'G'B', 12 bit

Datenfluss («Video»)

- Matroska, FFV1, «HD», Y'C_BC_R 4:4:4, 10 bit
- Matroska, FFV1, «HD», Y'C_BC_R 4:4:4, 12 bit

Ton

- Matroska, FLAC, 192 kHz, 24 bit

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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

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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, 48 kHz, 16 bit
- AAC, 96 kHz, 16 bit

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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

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Container:

- Ordner
- TAR
- ZIP
- MXF
- Matroska
- AXF

Codec:

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

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Vor- und Nachteile

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

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Eine Brücke zwischen den zwei Welten

RAWcooked (CLI)

→ mediaarea.net/RAWcooked

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RAWcooked

- encoding into Matroska (.mkv) using FFV1 video codec and FLAC audio codec
- all metadata preserved
- decoding with bit-by-bit reversibility
- possibility to embed sidecar files (e.g. MD5, LUT, XML)
- compatibility with media players

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MXF-Container (.mxf)

Videocodec

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

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SMPTE RDD 48:2018

SMPTE REGISTERED DISCLOSURE DOCUMENT



MXF Archive and Preservation Format Registered Disclosure Document

Page 1 of 113

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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:

Kate Murray
Library of Congress
101 Independence Ave, S.E.
Washington, DC 20540-1300

Email: kmur@loc.gov

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MXF / DPX

MXF

→ SMPTE RDD 48:2018

DPX

→ SMPTE ST 268M:2015

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MXF / JPEG 2000

MXF

→ SMPTE RDD 48:2018

JPEG 2000

→ ISO/IEC 15444-1:2019

→ usw.

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MXF / DN_x

MXF

→ SMPTE RDD 48:2018

DN_xHD, DN_xHR

→ nicht veröffentlicht

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MXF / ProRes

MXF

→ SMPTE RDD 48:2018

ProRes 422, ProRes 4444

→ SMPTE RDD 36:2015

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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

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Matroska-Container (.mkv)

Videocodec

- FFV1
- ProRes 422, ProRes 4444

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Matroska / FFV1

Matroska (.mkv)

→ IETF Internet Draft

FFV1

→ IETF RFC 9043

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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>.

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Matroska / ProRes

Matroska (.mkv)

→ IETF Internet Draft

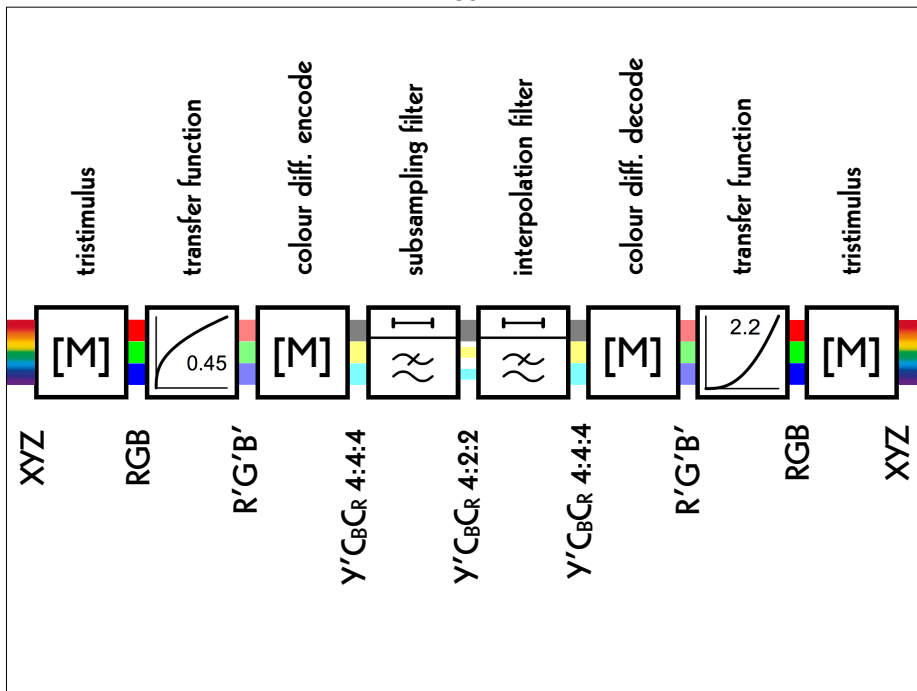
ProRes 422, ProRes 4444

→ SMPTE RDD 36:2015

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Umwandlungen

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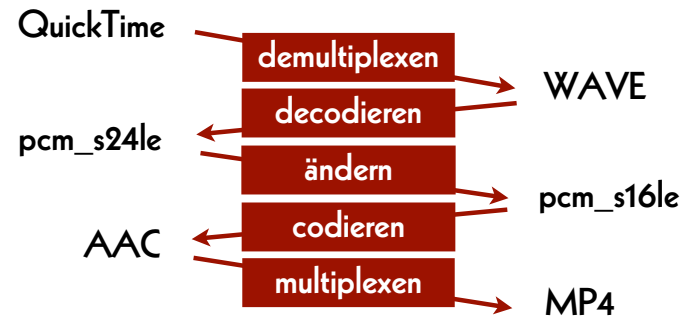
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Dateiumwandlungen

demultiplexen
decodieren
ändern
codieren
multiplexen

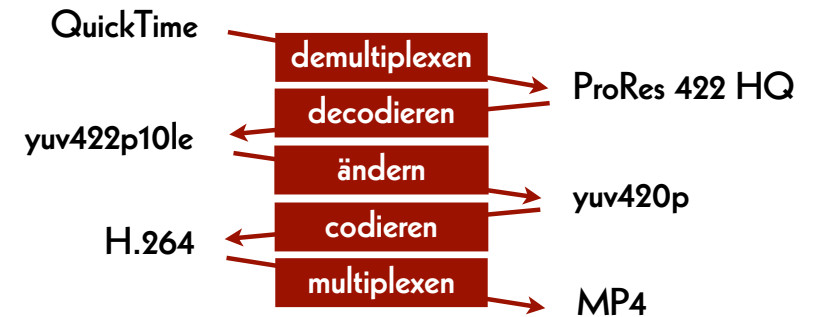
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Beispiel: Ton



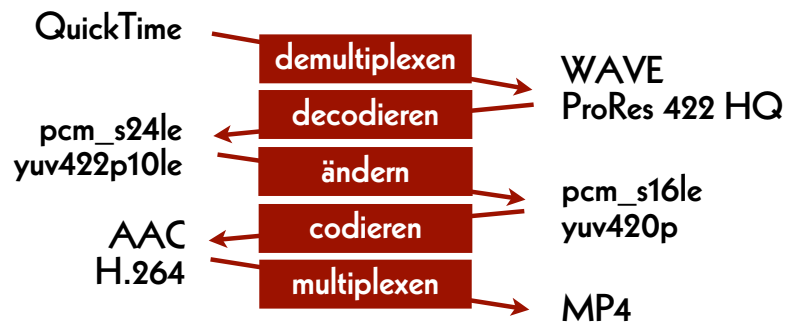
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Beispiel: Bild



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Beispiel: Bild und Ton



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Danksagung (1)

- Eidgenössische Technische Hochschule
- Massachusetts Institute of Technology
- Kinemathek Lichtspiel, Bern
- Charles Poynton
- Dave Rice und Misty De Meo
- Agathe Jarczyk und David Pfluger

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Danksagung (2)

- Tommy Aschenbach
- Claudio Weidmann
- Jim Lindner
- Carl Eugen Hoyos
- Peter Bubestinger-Steindl
- Jérôme Martinez
- Michael Niedermayer

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