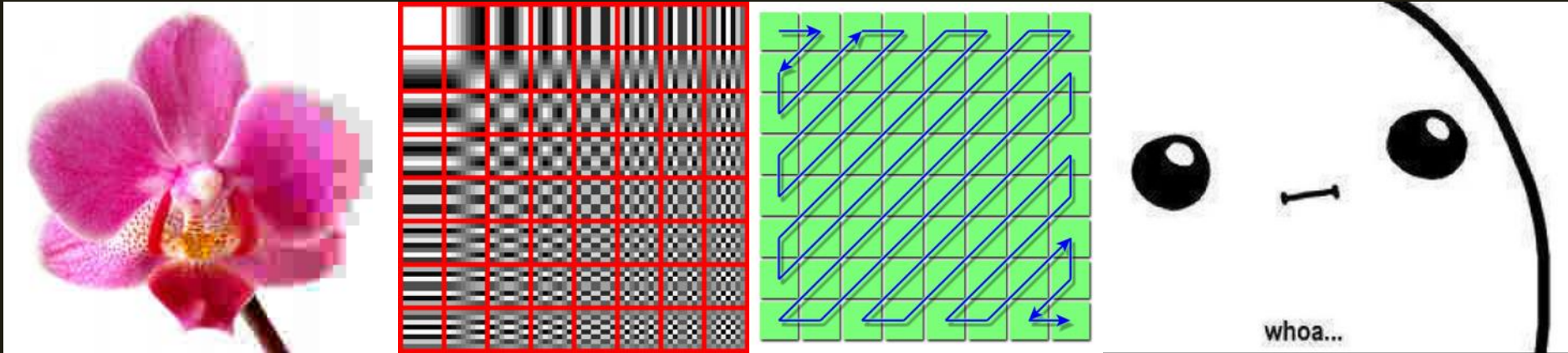


Multimedia: JPEG

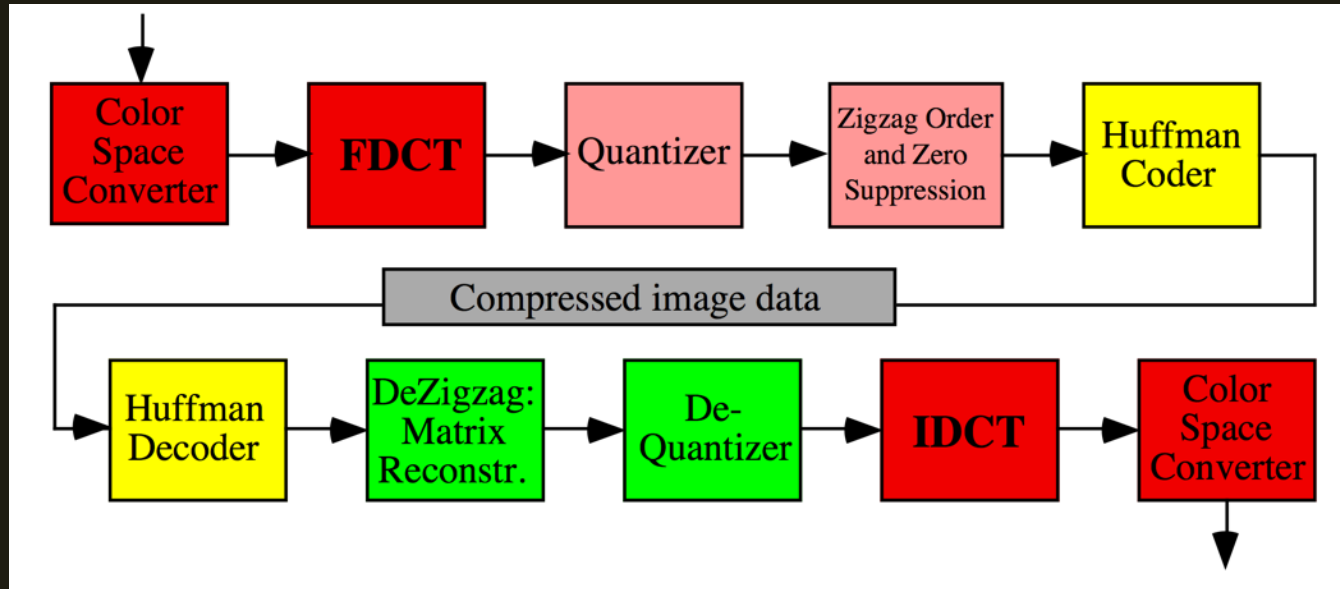


Jonas Treumer / Ben Lorenz

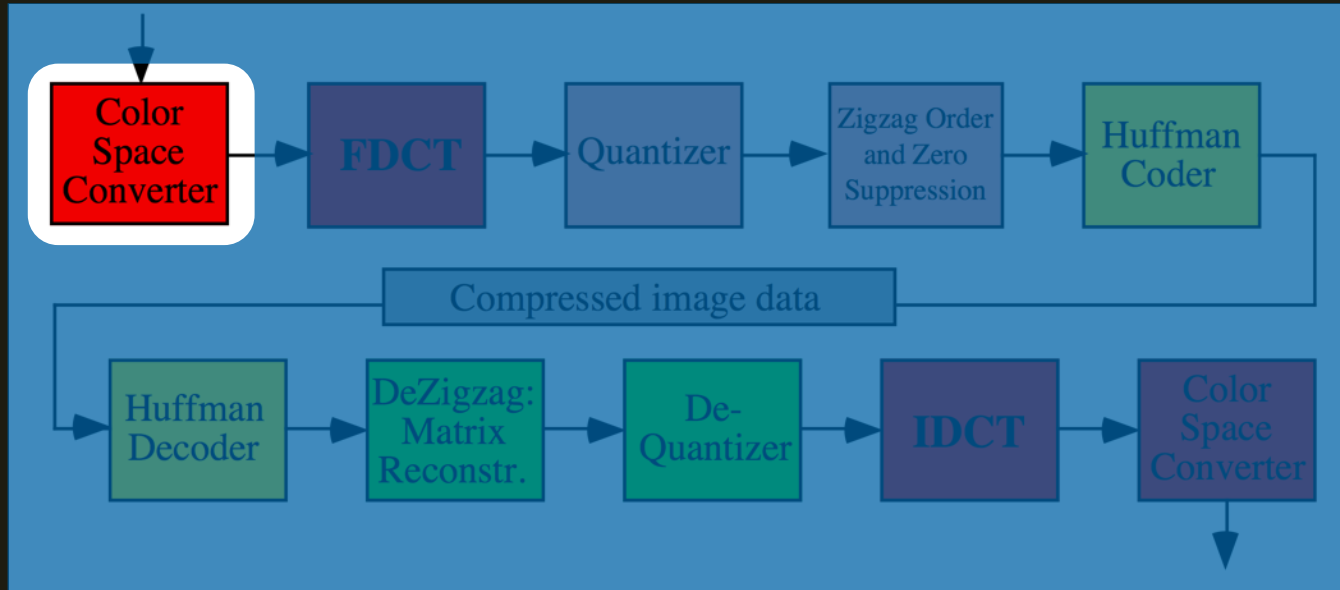
JFIF – JPEG File Interchange Format

- 1992 vorgestellt als ISO/IEC 10918-1 bzw. CCITT T.81
- JPEG-Norm → verschiedene Komprimierungsmethoden für Bilder
- JFIF speichert Bilddaten, Dekomprimierungsinformationen sowie Zusatzdaten
- JFIF unterstützt nicht die gesamten Möglichkeiten von JPEG

JPEG Kompression/Dekompression

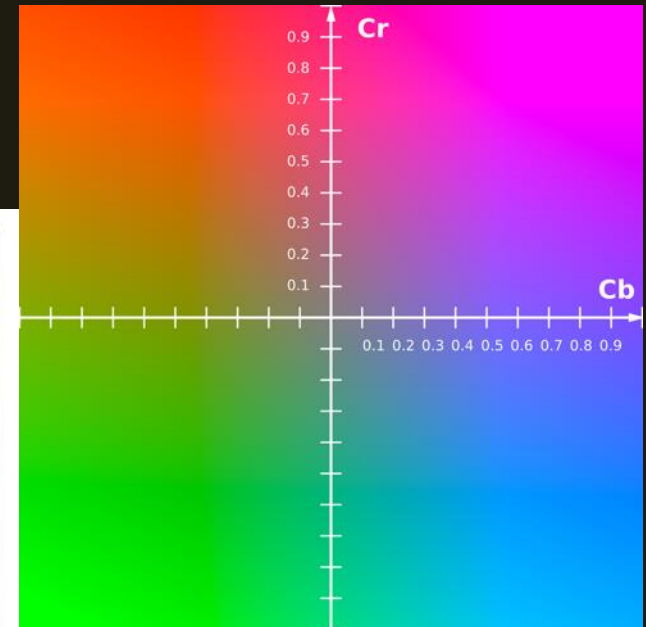
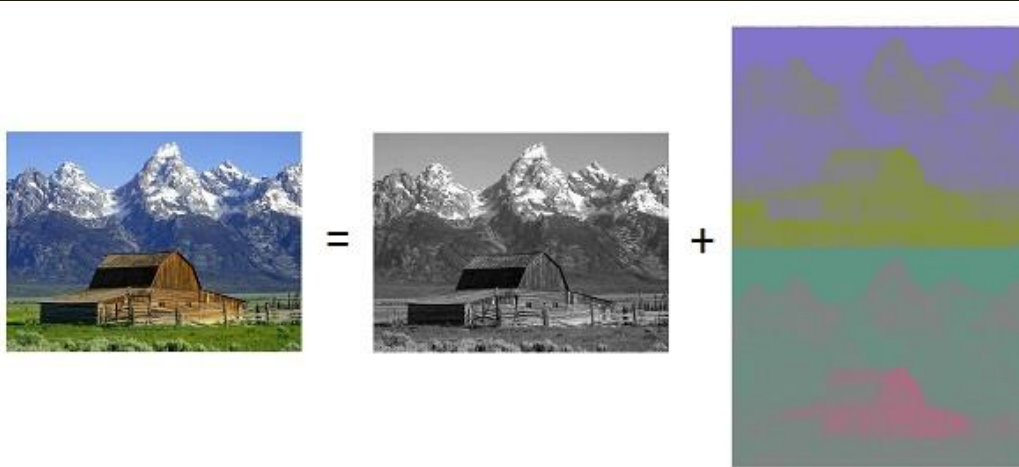


JPEG Kompression/Dekompression



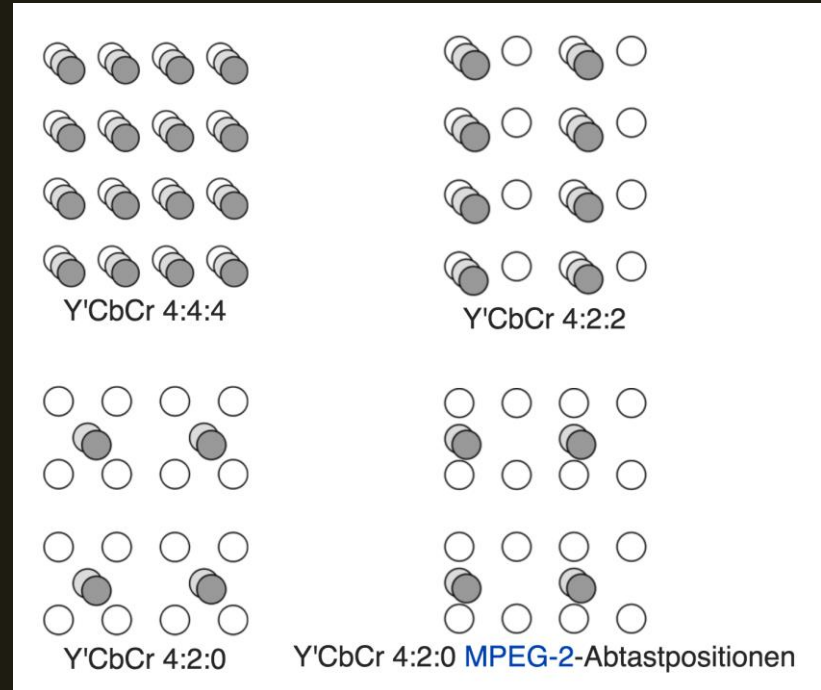
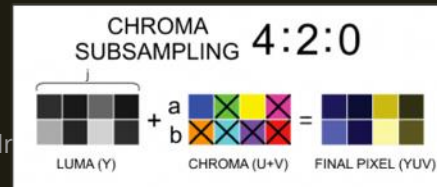
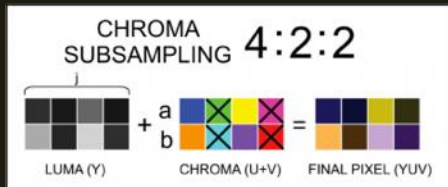
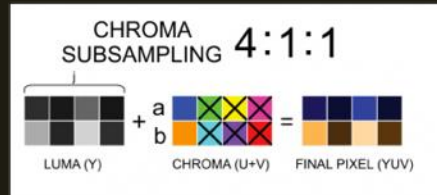
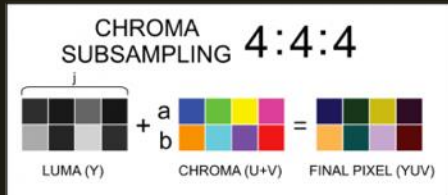
YCbCr-Farbmodell

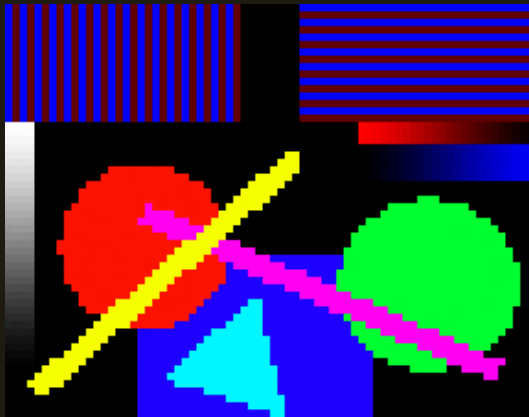
- Y = Helligkeitsachse aus CIE-Normvalenzsystem
- Cb, Cr = Chrominance „Buntheit“
- Cb = blue – yellow
- Cr = red – green



YCbCr-Chroma-Subsampling

- Datenreduktion
- Chrominanz ggü. Luminanz mit geringerer Abtastrate
- Geringer optischer Qualitätsverlust





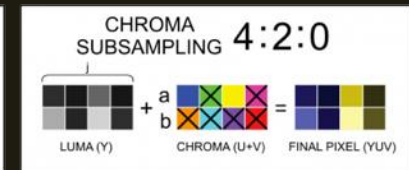
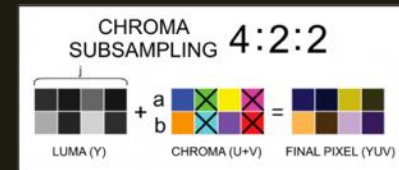
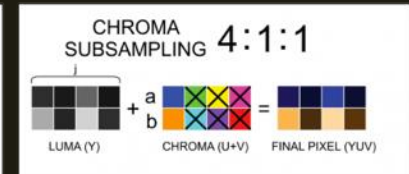
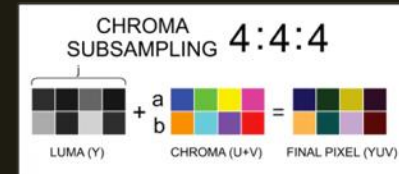
4:4:4



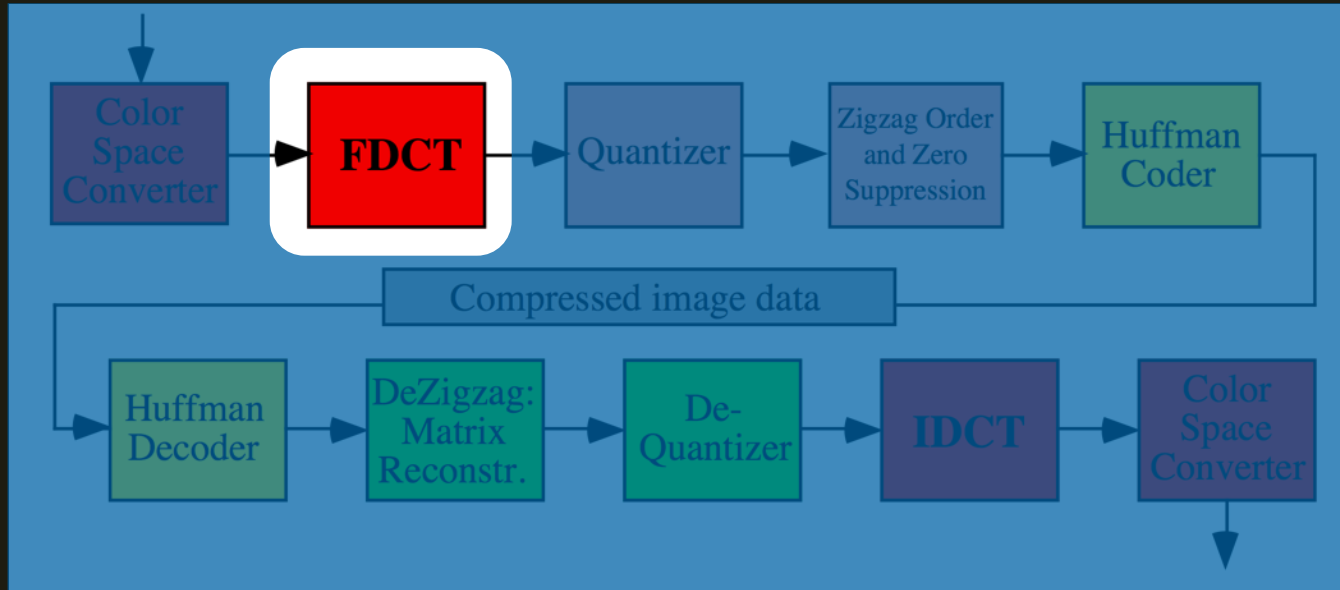
4:2:2



4:2:0

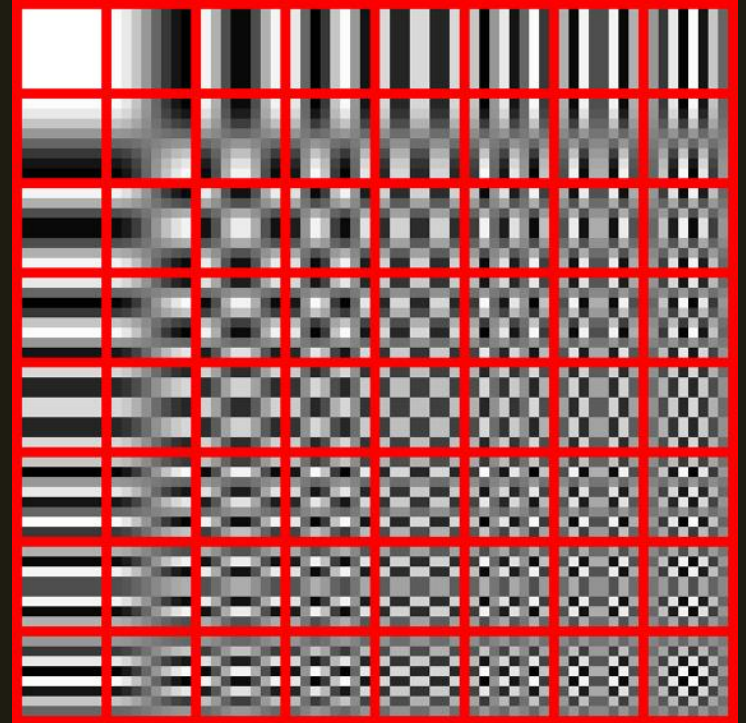


JPEG Kompression/Dekompression



JPEG Kompression – FDCT

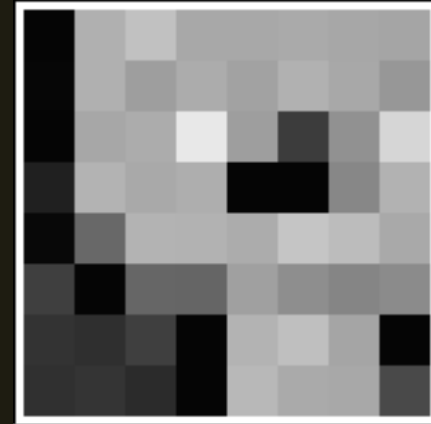
- Je 8x8 Block im Bild
 - Linearkombination aus 8x8 2D-Cosinusbasisfunktionen



JPEG Kompression – FDCT

- Helligkeitswerte des 8x8 Blocks

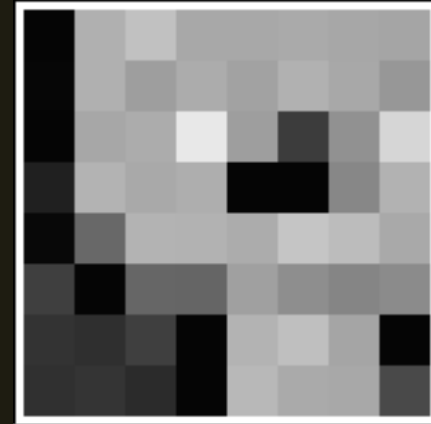
5	176	193	168	168	170	167	165
6	176	158	172	162	177	168	151
5	167	172	232	158	61	145	214
33	179	169	174	5	5	135	178
8	104	180	178	172	197	188	169
63	5	102	101	160	142	133	139
51	47	63	5	180	191	165	5
49	53	43	5	184	170	168	74



JPEG Kompression – FDCT

- Normalisierte Helligkeitswerte

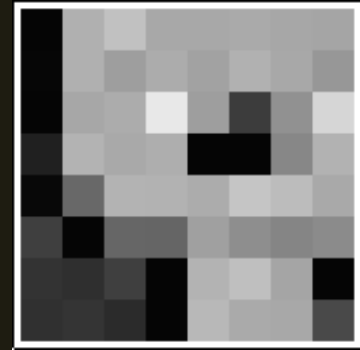
-122	49	66	41	41	43	40	38
-121	49	31	45	35	50	41	24
-122	40	45	105	31	-66	18	87
-94	52	42	47	-122	-122	8	51
-119	-23	53	51	45	70	61	42
-64	-122	-25	-26	33	15	6	12
-76	-80	-64	-122	53	64	38	-122
-78	-74	-84	-122	57	43	41	-53



JPEG Kompression – FDCT

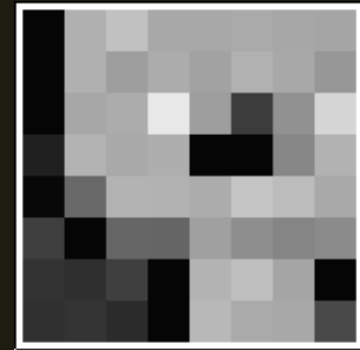
- Koeffizienten berechnen (lineare Algebra)

$$X = U * A * U^T$$



$$U = \frac{1}{2} \begin{bmatrix} \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \\ \cos \frac{\pi}{16} & \cos \frac{3\pi}{16} & \cos \frac{5\pi}{16} & \cos \frac{7\pi}{16} & \cos \frac{9\pi}{16} & \cos \frac{11\pi}{16} & \cos \frac{13\pi}{16} & \cos \frac{15\pi}{16} \\ \cos \frac{2\pi}{16} & \cos \frac{6\pi}{16} & \cos \frac{10\pi}{16} & \cos \frac{14\pi}{16} & \cos \frac{18\pi}{16} & \cos \frac{22\pi}{16} & \cos \frac{26\pi}{16} & \cos \frac{30\pi}{16} \\ \cos \frac{3\pi}{16} & \cos \frac{9\pi}{16} & \cos \frac{15\pi}{16} & \cos \frac{21\pi}{16} & \cos \frac{27\pi}{16} & \cos \frac{33\pi}{16} & \cos \frac{39\pi}{16} & \cos \frac{45\pi}{16} \\ \cos \frac{4\pi}{16} & \cos \frac{12\pi}{16} & \cos \frac{20\pi}{16} & \cos \frac{28\pi}{16} & \cos \frac{36\pi}{16} & \cos \frac{44\pi}{16} & \cos \frac{52\pi}{16} & \cos \frac{60\pi}{16} \\ \cos \frac{5\pi}{16} & \cos \frac{15\pi}{16} & \cos \frac{25\pi}{16} & \cos \frac{35\pi}{16} & \cos \frac{45\pi}{16} & \cos \frac{55\pi}{16} & \cos \frac{65\pi}{16} & \cos \frac{75\pi}{16} \\ \cos \frac{6\pi}{16} & \cos \frac{18\pi}{16} & \cos \frac{30\pi}{16} & \cos \frac{42\pi}{16} & \cos \frac{54\pi}{16} & \cos \frac{66\pi}{16} & \cos \frac{78\pi}{16} & \cos \frac{90\pi}{16} \\ \cos \frac{7\pi}{16} & \cos \frac{21\pi}{16} & \cos \frac{35\pi}{16} & \cos \frac{49\pi}{16} & \cos \frac{63\pi}{16} & \cos \frac{77\pi}{16} & \cos \frac{91\pi}{16} & \cos \frac{105\pi}{16} \end{bmatrix}$$

-122	49	66	41	41	43	40	38
-121	49	31	45	35	50	41	24
-122	40	45	105	31	-66	18	87
-94	52	42	47	-122	-122	8	51
-119	-23	53	51	45	70	61	42
-64	-122	-25	-26	33	15	6	12
-76	-80	-64	-122	53	64	38	-122
-78	-74	-84	-122	57	43	41	-53



JPEG Kompression – FDCT

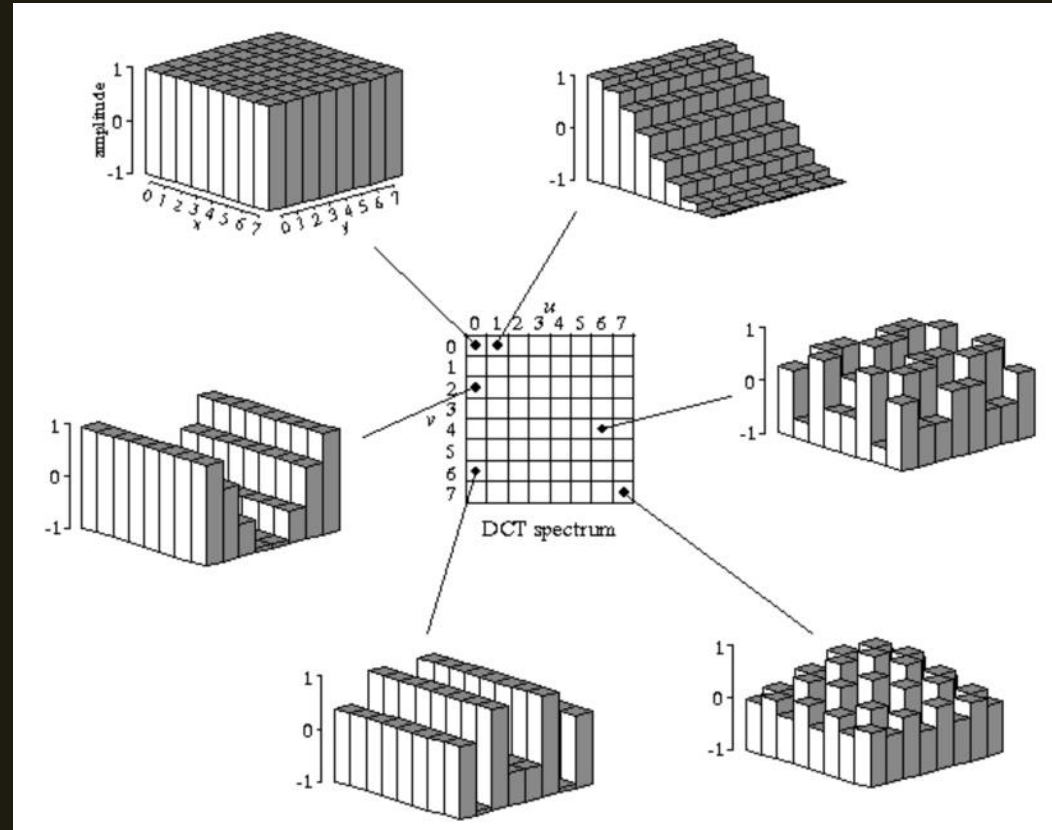
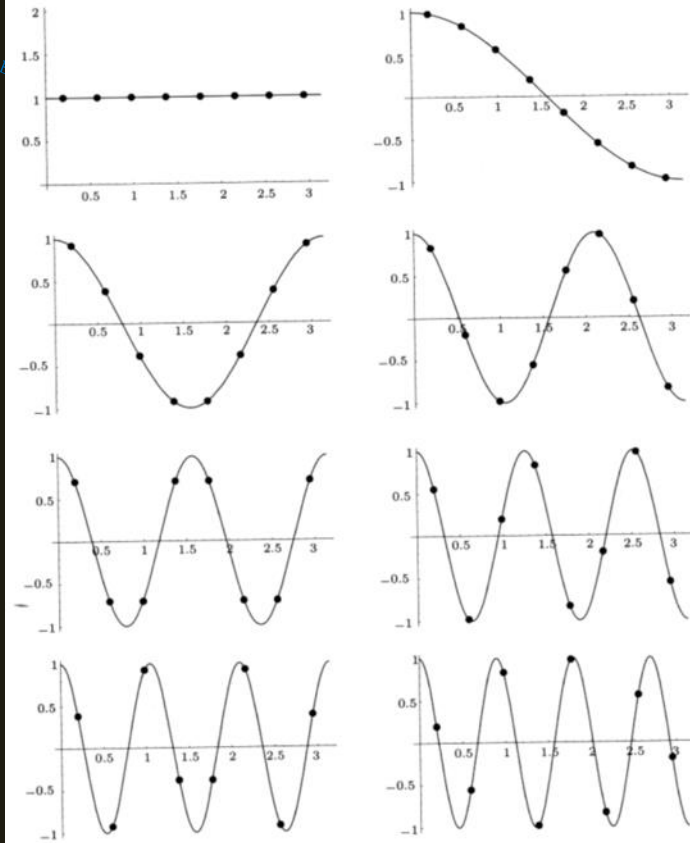
$$X_{p,q} = \alpha_p \alpha_q \sum_{m=0}^7 \sum_{n=0}^7 A_{m,n} * \cos \frac{\pi(2m+1)p}{16} * \cos \frac{\pi(2n+1)q}{16}$$

-122	49	66	41	41	43	40	38
-121	49	31	45	35	50	41	24
-122	40	45	105	31	-66	18	87
-94	52	42	47	-122	-122	8	51
-119	-23	53	51	45	70	61	42
-64	-122	-25	-26	33	15	6	12
-76	-80	-64	-122	53	64	38	-122
-78	-74	-84	-122	57	43	41	-53



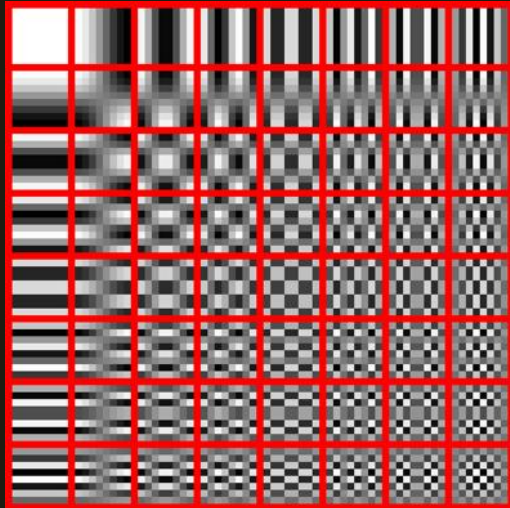
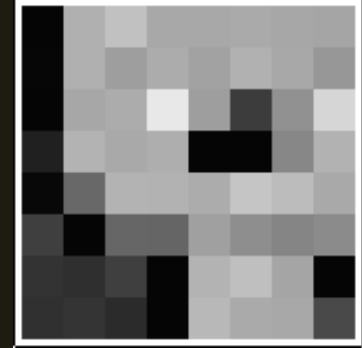
-27.500	-213.468	-149.608	-95.281	-103.750	-46.946	-58.717	27.226
168.229	51.611	-21.544	-239.520	-8.238	-24.495	-52.657	-96.621
-27.198	-31.236	-32.278	173.389	-51.141	-56.942	4.002	49.143
30.184	-43.070	-50.473	67.134	-14.115	11.139	71.010	18.039
19.500	8.460	33.589	-53.113	-36.750	2.918	-5.795	-18.387
-70.593	66.878	47.441	-32.614	-8.195	18.132	-22.994	6.631
12.078	-19.127	6.252	-55.157	85.586	-0.603	8.028	11.212
71.152	-38.373	-75.924	29.294	-16.451	-23.436	-4.213	15.624

DCT II - Koeffizienten



JPEG Kompression – FDCT

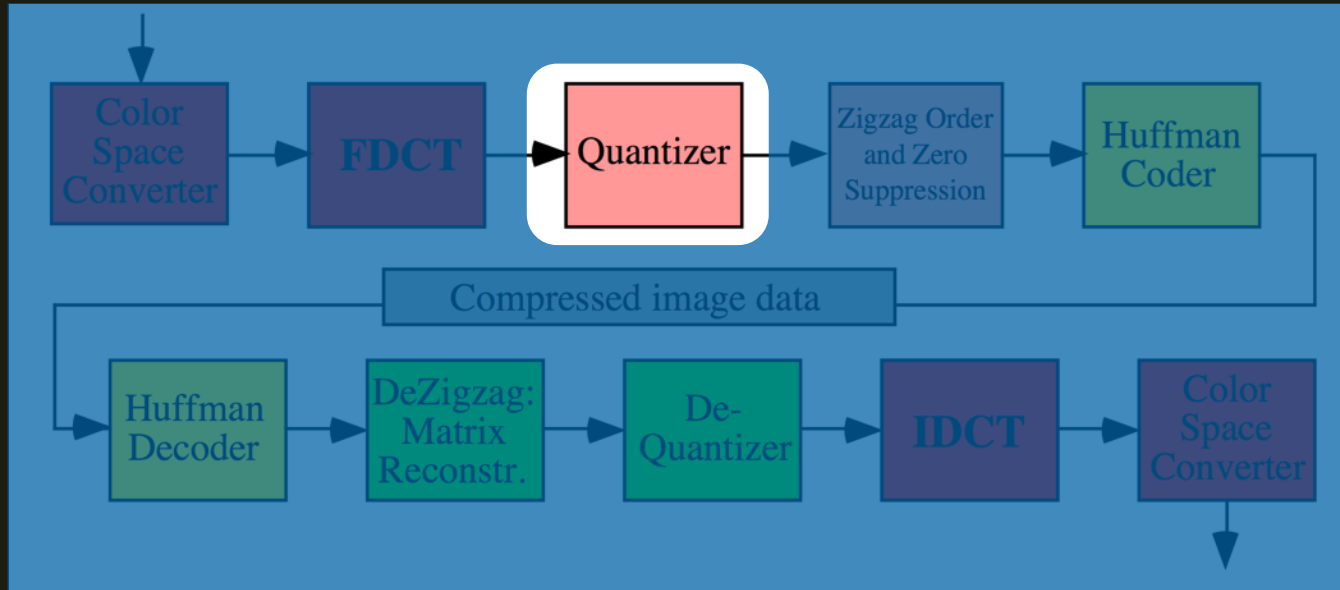
- $X_{0,0}$: Gleichspannungs- bzw. DC-Koeffizient, „Grundfarbe“
- $X_{p,q}$: Wechspannungsanteile bzw. AC-Koeffizienten



-27.500	-213.468	-149.608	-95.281	-103.750	-46.946	-58.717	27.226
168.229	51.611	-21.544	-239.520	-8.238	-24.495	-52.657	-96.621
-27.198	-31.236	-32.278	173.389	-51.141	-56.942	4.002	49.143
30.184	-43.070	-50.473	67.134	-14.115	11.139	71.010	18.039
19.500	8.460	33.589	-53.113	-36.750	2.918	-5.795	-18.387
-70.593	66.878	47.441	-32.614	-8.195	18.132	-22.994	6.631
12.078	-19.127	6.252	-55.157	85.586	-0.603	8.028	11.212
71.152	-38.373	-75.924	29.294	-16.451	-23.436	-4.213	15.624

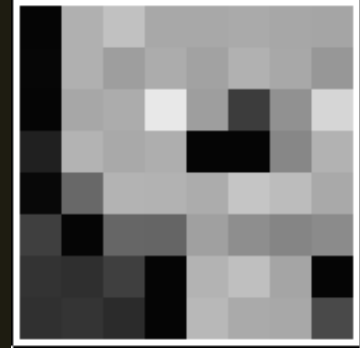
DCT II - Koeffizienten

JPEG Kompression/Dekompression

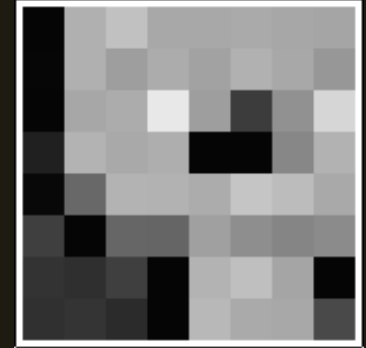


JPEG Kompression – Quantisierung

- Hohe Frequenzen entfernen (Irrelevanzreduktion)
- Jpeg 50% Quality Quantisierungsmatrix

$$Q = \begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$


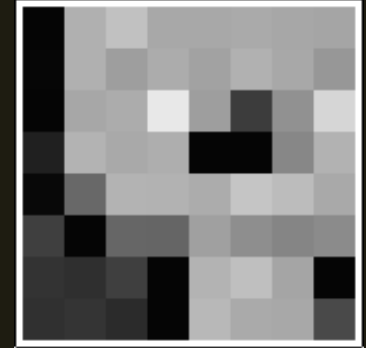
JPEG Kompression – Quantisierung



$$B_{p,q} = \text{round}\left(\frac{X_{p,q}}{Q_{p,q}}\right)$$

$$Q = \begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

JPEG Kompression – Quantisierung



$$B_{p,q} = \text{round}\left(\frac{X_{p,q}}{Q_{p,q}}\right)$$

-2	-19	-15	-6	-4	-1	-1	0
14	4	-2	-13	0	0	-1	-2
-2	-2	-2	7	-1	-1	0	1
2	-3	-2	2	0	0	1	0
1	0	1	-1	-1	0	0	0
-3	2	1	-1	0	0	0	0
0	0	0	-1	1	0	0	0
1	0	-1	0	0	0	0	0

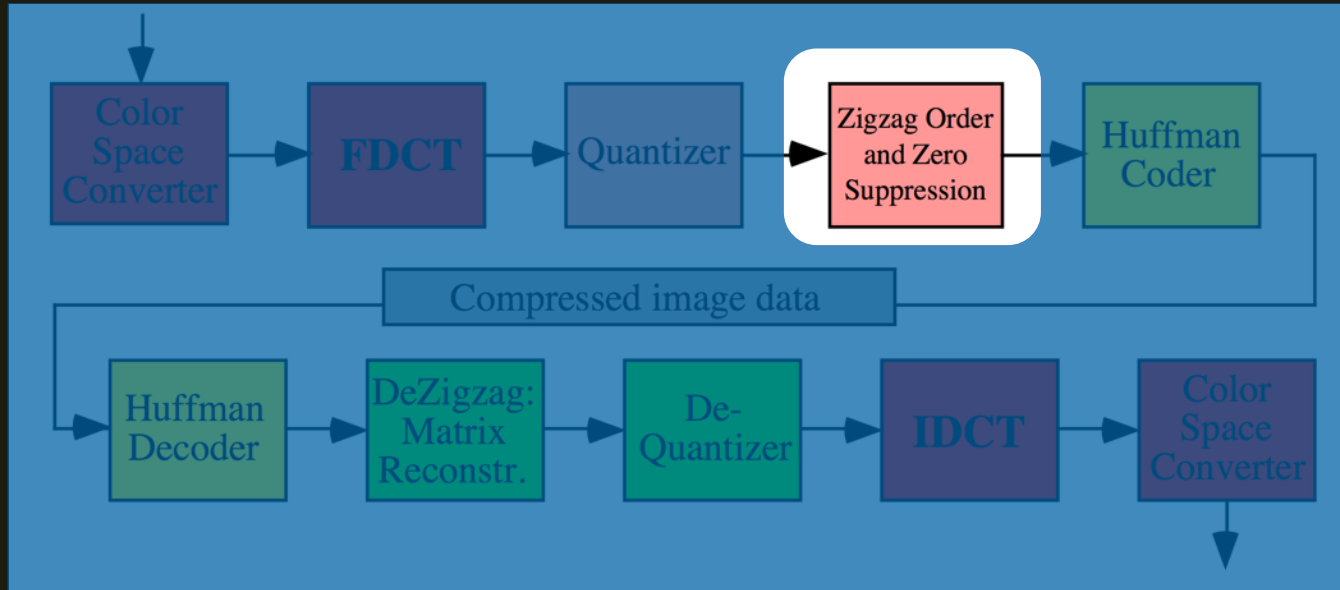
JPEG Qualitätsparameter

- Qualitätsparameter bzw. Regelung des Kompressionsgrades?
 - Unterschiedliche Quantisierungsmatrizen oder
 - q_{JPEG} als Parameter – Wertebereich $1 \leq q_{JPEG} \leq 99$
 - Ergibt α als Faktor für Quantisierungsmatrix

$$a = \frac{50}{q_{JPEG}} \quad \text{für } 1 \leq q_{JPEG} \leq 50$$

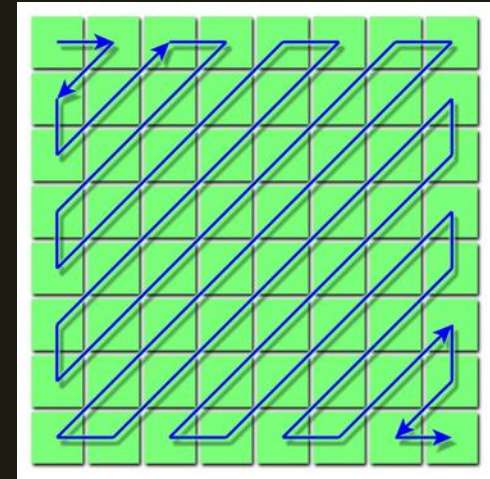
$$a = 2 - \frac{2q_{JPEG}}{100} \quad \text{für } 50 \leq q_{JPEG} \leq 99$$

JPEG Kompression/Dekompression



JPEG Kompression – ZigZag & Zero Suppression

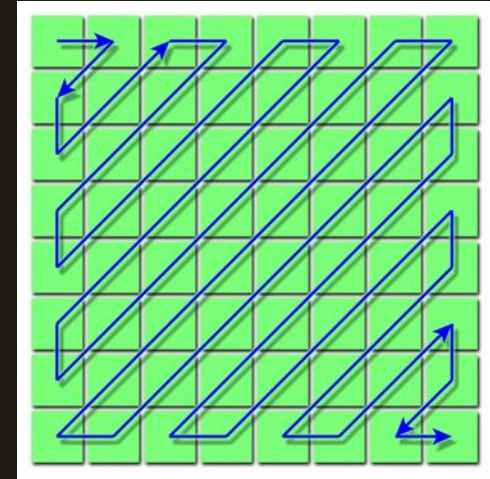
-2	-19	-15	-6	-4	-1	-1	0
14	4	-2	-13	0	0	-1	-2
-2	-2	-2	7	-1	-1	0	1
2	-3	-2	2	0	0	1	0
1	0	1	-1	-1	0	0	0
-3	2	1	-1	0	0	0	0
0	0	0	-1	1	0	0	0
1	0	-1	0	0	0	0	0



JPEG Kompression – ZigZag & Zero Suppression

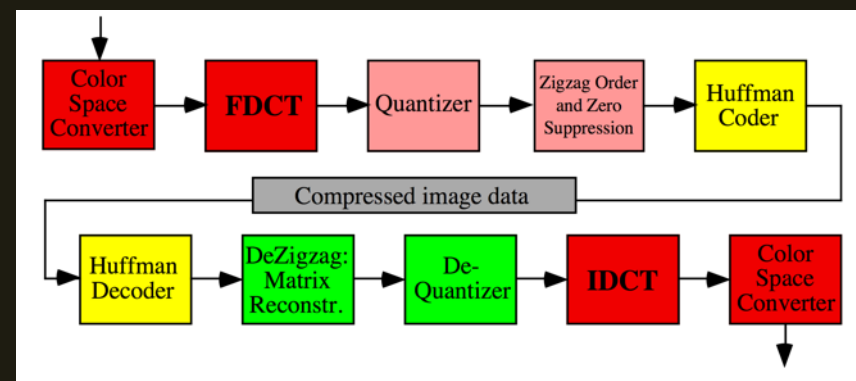
-2	-19	-15	-6	-4	-1	-1	0
14	4	-2	-13	0	0	-1	-2
-2	-2	-2	7	-1	-1	0	1
2	-3	-2	2	0	0	1	0
1	0	1	-1	-1	0	0	0
-3	2	1	-1	0	0	0	0
0	0	0	-1	1	0	0	0
1	0	-1	0	0	0	0	0

-2 -19 14 -2 ... 0 0 0 0 0 0 0 0
+LaufLängenkodierung



JPEG Kompression

- RGB zu YCbCr (verlustbehaftet)
- YCbCr Color Subsampling (verlustbehaftet)
- 8x8 Blöcke und DCT II (theoretisch verlustfrei, Verlust durch Rundungsfehler)
- Quantisierung (verlustbehaftet)
- ZigZag + Zero-Suppression (verlustfrei)
- Huffman-Kodierung (verlustfrei)



JPEG Modi

- Bisher: nur baseline sequential JPEG
 - Top to bottom Anordnung
 - Gesamtes Bild kann nur nach Abschluss der Übertragung ganz betrachtet werden
- Lösung: Progressive JPEG
 - Verteilung in mehrere Scans mit wachsendem Detailgrad



Sequential
JPEG



Progressive
JPEG

JPEG – Artefakte/Probleme

- 8x8 Blöcke sichtbar
- Bei starker Kompression

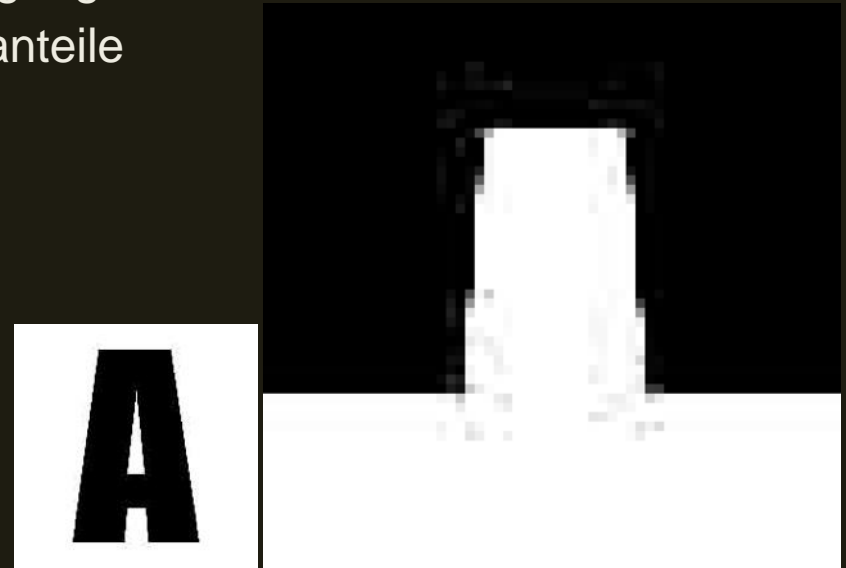


JPEG – Artefakte/Probleme

- Überschwingen an scharfen Übergängen
- Ursache: fehlende Hochfrequenzanteile



PNG



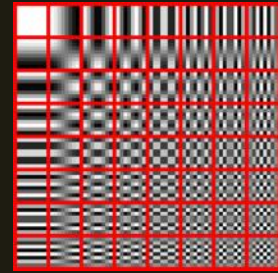
JPEG

DCT II

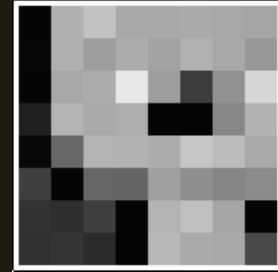
$$X = U * A * U^T$$

Geeignete Faktoren vor U -> U orthogonal

X



A



DCT II

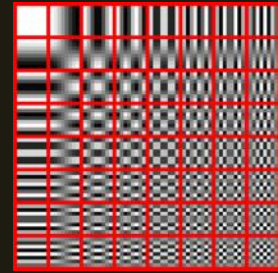
$$X = U * A * U^T$$

Geeignete Faktoren vor U -> U orthogonal

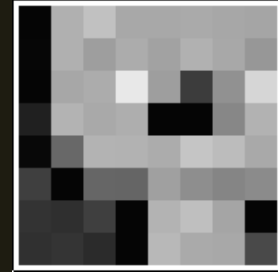
$$U^T = U^{-1}$$

$$\begin{aligned} U * U^{-1} &= I & U^{-1} * U &= I \\ U * U^T &= I & U^T * U &= I \end{aligned}$$

X



A



DCT II

$$X = U * A * U^T$$

Geeignete Faktoren vor U -> U orthogonal

$$U^T = U^{-1}$$

$$U * U^{-1} = I \quad U^{-1} * U = I$$

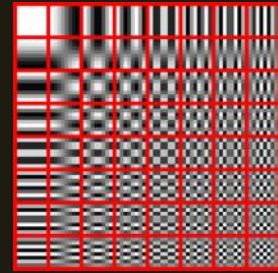
$$U * U^T = I \quad U^T * U = I$$

IDCT Herleitung

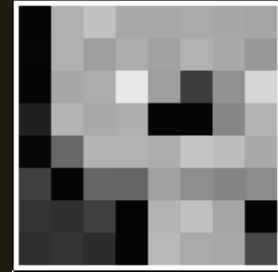
$$X = U * A * U^T$$

$$? = A$$

X



A



DCT II

$$X = U * A * U^T$$

Geeignete Faktoren vor U -> U orthogonal

$$U^T = U^{-1}$$

$$U * U^{-1} = I \quad U^{-1} * U = I$$

$$U * U^T = I \quad U^T * U = I$$

IDCT Herleitung

$$X = U * A * U^T$$

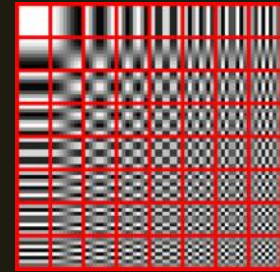
$$U^T * X * U = U^T * U * A * U^T * U$$

$$U^T * X * U = (U^T * U) * A * (U^T * U)$$

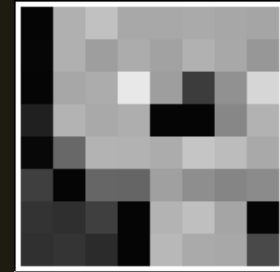
$$U^T * X * U = I * A * I$$

$$U^T * X * U = A$$

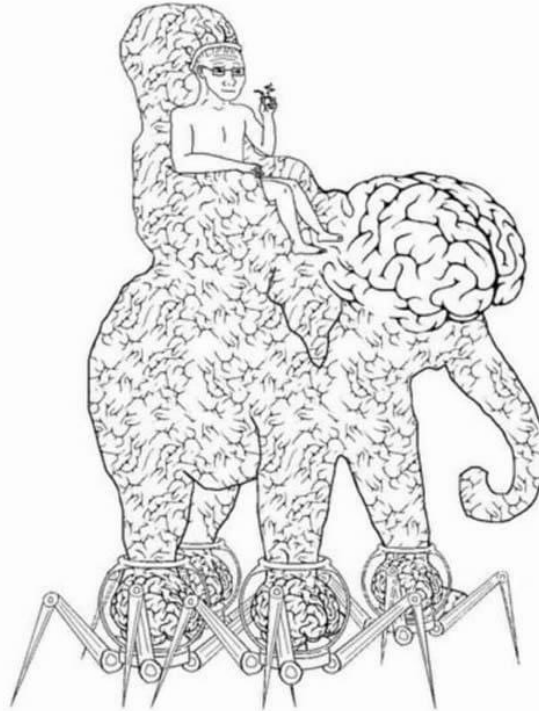
X



A



When you understand



DCT II and IDCT