Video Coding Scientific Breakthroughs

The three discoveries every modern video codec rests on. Companion to article 3.2 of Block 3 (Codec Evolution). Print on A4 or US Letter.

1 · Information Theory (1948–1959)

Claude Shannon, Bell Labs

- Defines entropy H = − sum p_i log2 p_i: the bit-floor for lossless compression.
- Rate-distortion R(D): the lowest bit rate for a given allowed distortion.
- Every BD-rate, every bits-per-pixel score, every 'we saved X percent' claim is measured against this curve. Without it there is no way to score progress.

Milestones: Shannon 1948 · Shannon 1959 R(D) · Huffman 1952 · Arithmetic coding 1976

2 · Prediction (1969–1981)

Mounts, Netravali, Robbins, Jain and Jain

- Conditional replenishment (1969): skip blocks that did not change since the last frame.
- Motion-compensated prediction (1979): describe motion with a small displacement vector.
- Block-matching motion estimation (1981): the algorithm every codec since H.261 ships.
- Residual after good prediction has roughly 10× less entropy than the raw frame.

Milestones: Mounts 1969 · Netravali-Robbins 1979 · Jain-Jain 1981 · Intra prediction H.264 2003

3 · Transform (1974)

Nasir Ahmed, T. Natarajan, K. R. Rao

- DCT-II rewrites an 8x8 pixel block as 64 frequency coefficients.
- Energy compacts to the top-left; quantize the rest cheaply.
- Approximates the optimal KLT to within fractions of a dB at tiny computational cost.
- Integer-DCT variants in H.264, HEVC, AV1, AV2 are exactly invertible.

Milestones: Ahmed-Natarajan-Rao 1974 · JPEG 1992 · H.264 integer DCT 2003 · AV1 ADST 2018

Hybrid encoder pipeline (same since H.261 in 1988)

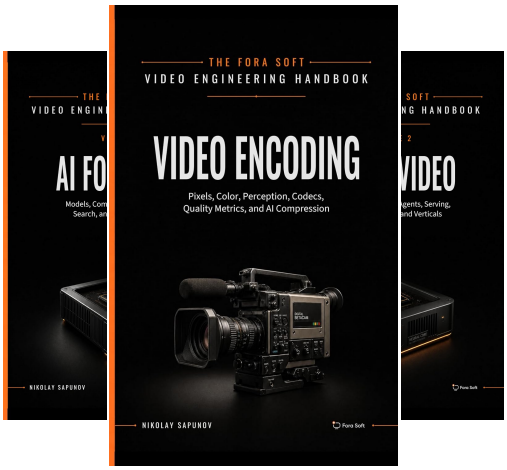
Input block → Prediction → Residual → Transform → Quantization → Entropy coding → Bitstream

Encoder also runs inverse-quant + inverse-transform + in-loop filter to build the reference frame buffer.

Rate-distortion optimisation J = D + lambda * R is the algorithm that picks among all coding modes.

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This cheat sheet traces modern codecs to three ideas: information theory, prediction and the transform. We wrote seven volumes on the stack built on them. Volume 1 covers compression from pixels to H.264, HEVC and AV1, Volume 6 computer vision on video, and Volume 7 real-time pipelines.

WHAT YOU WILL FIND INSIDE

- Entropy coding, prediction and transforms
- Rate-distortion and quality metrics
- H.264, HEVC and AV1 coding tools
- Computer vision for video analytics

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