JPEG

An overview of recent and emerging JPEG formats for digital archival and long-term preservation

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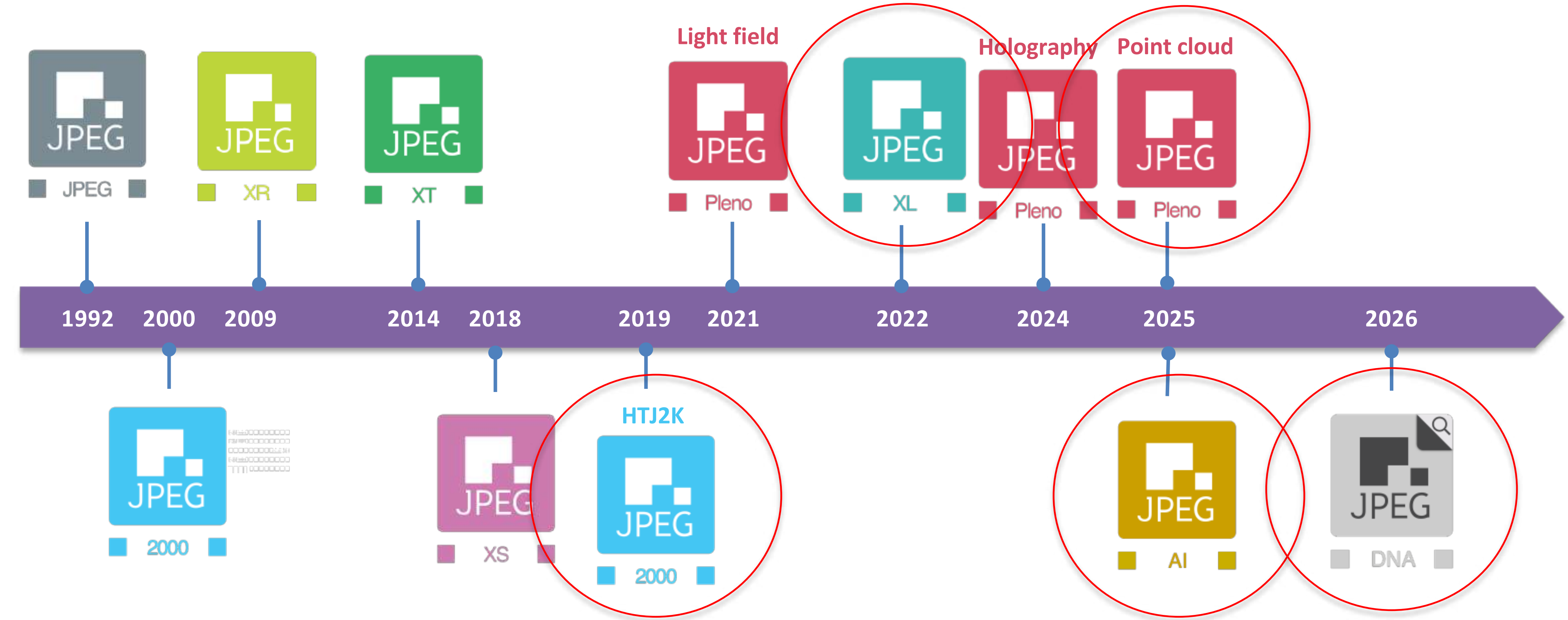
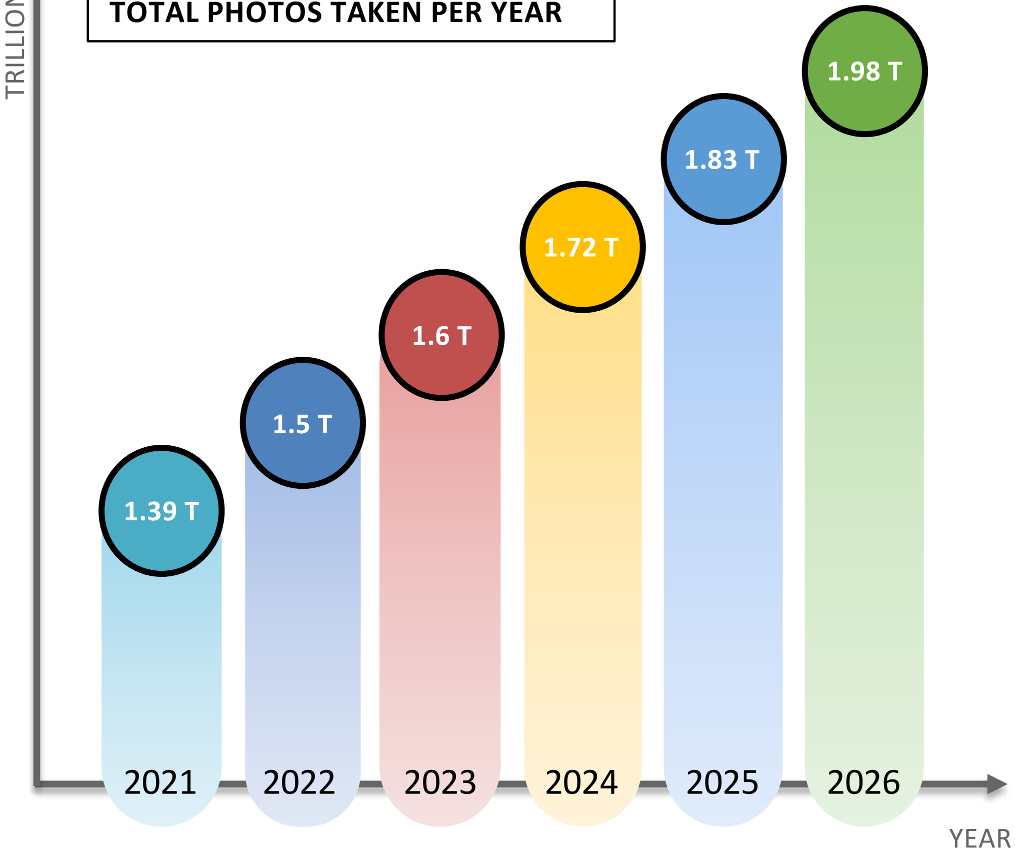
An evolving family of coding standards

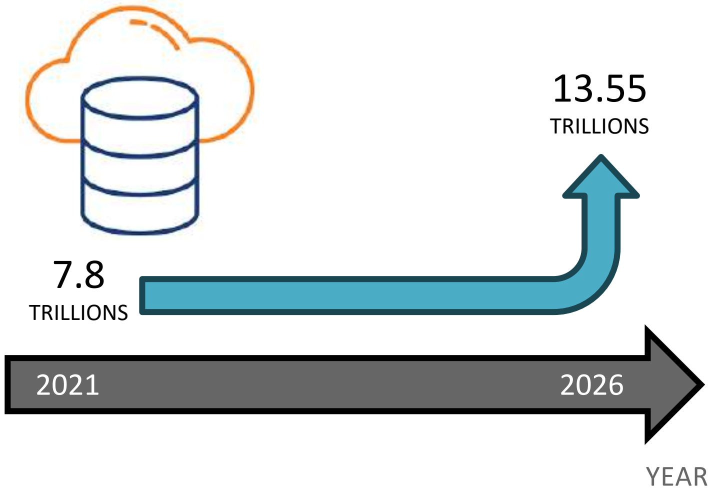


Observation

TOTAL PHOTOS TAKEN PER YEAR



ESTIMATED NUMBER OF STORED PHOTOS



Statistics from
https://news.mylio.com/how-many-photos-taken-in-2022/

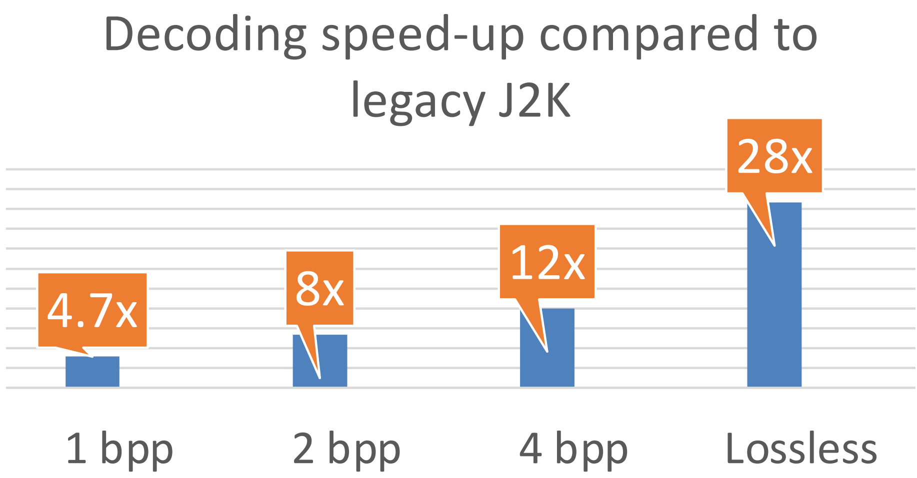
JPEG

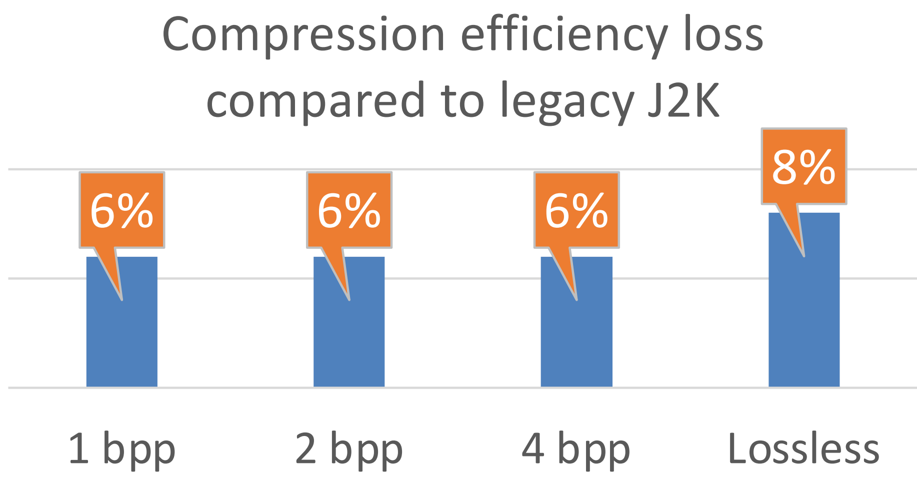
HTJ2K

JPEG 2000

JPEG 2000

HTJ2K – A faster J2K!





High Throughput JPEG 2000 (ISO/IEC 15444-15)
Architecture

Numerically lossless transcoding of HTJ2K to/from legacy JPEG 2000

Features of JPEG 2000 & HTJ2K

- Up to 16’384 channels
- Up to 38 bits per sample
- Up to 4’294’967’295 pixels per dimension
- Lossy and lossless coding
- Progressive encoding and decoding
  - Quality
  - Resolution
  - Position
  - Channels
- Non-iterative optimal rate control
  - Single-pass
  - Comparable encode and decode complexity
- From sub-frame to full-frame latency
- Royalty-free

JPEG 2000 is widely used

Domain	Example standard
Geospatial imaging	National Imagery Transmission Format (NITF)
Cinema	D-Cinema Package (DCP)
Media archival	Interoperable Master Format (IMF)
Document management	Portable Document Format (PDF)
Cultural Heritage	FADGI Technical Guidelines for Digitizing Cultural Heritage Materials
Mass digitization	International Image Interoperability Framework (IIIF)
Medical	Digital Imaging and Communications in Medicine (DICOM)
Video-over-IP	Video Services Forum (VSF)

Large body of implementations

Comprimato
libheif
Accusoft
FFMPEG
OpenJPEG
ICT-Link
OpenHTJ2K
nvJPEG2000
Jasper
OpenJPH
Kakadu SDK
ISO reference software

… and others

FGPA CPU JS ASIC GPU

Open source and commercial

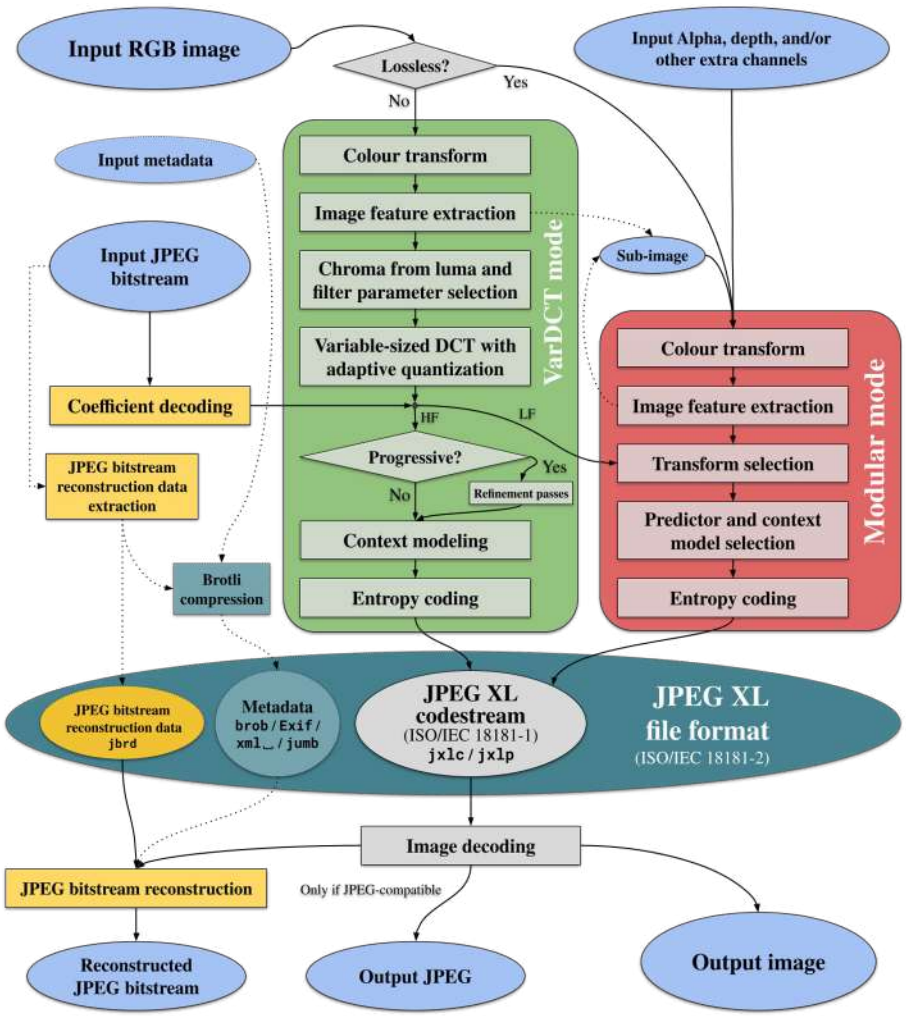
JPEG XL use cases and applications

General-purpose image compression:

- Web & mobile apps image delivery
  (Social media, cloud storage, websites, game assets, …)
- Photography (capture, editing, storage)
- Scientific imaging (multi-spectral, high-precision)
- Medical imaging
- Printing
- Archival
- …

JPEG XL architecture

- Lossless module
  Very flexible, signalled transforms and context model
- Lossy module (variable size DCT)
  Variable-sized DCT (2x2 to 256x256, including non-square);
  uses Modular for the 1:8 LF image and auxiliary signalling
- JPEG recompression
  Uses a subset of VarDCT mode (only 8x8)

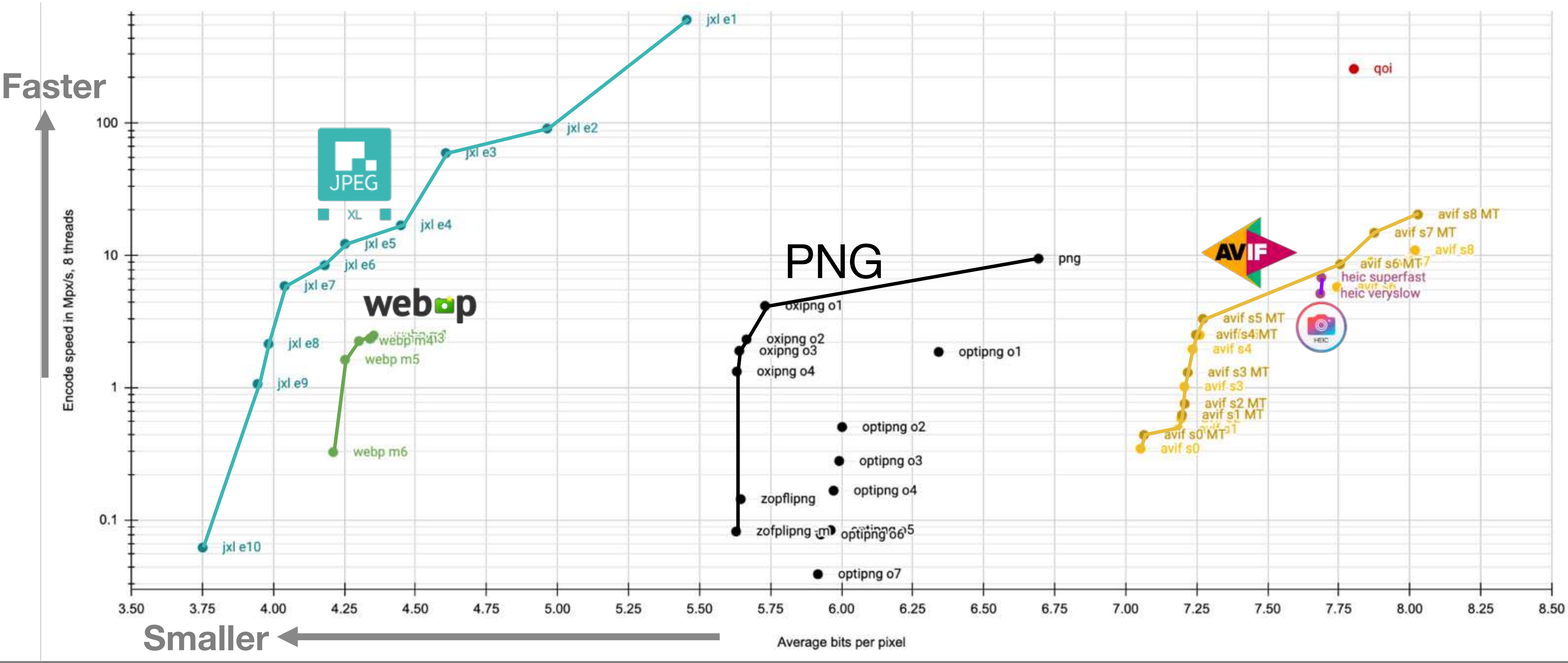


JPEG XL benefits

- Substantially **better compression**
  50% smaller than JPEG for the same quality, 30-50% smaller than PNG
- Legacy-friendly: **lossless JPEG recompression**
  20% file size reduction, bit-exact file reconstruction
- **High-fidelity**, high-precision, high dynamic range, consistent quality
  Visually lossless or mathematically lossless: best compression
- **Fast** encoding and decoding
  Designed to be fast on today's CPUs
- Optimized for **web delivery**
  Progressive decoding, minimal header overhead
- Perfect interchange format for **authoring workflows**
  Layers, selection masks, low generation loss
- Free to use for anyone: **royalty-free** and FOSS
  Not patent-encumbered, free and open source production-ready reference software available

JPEG XL

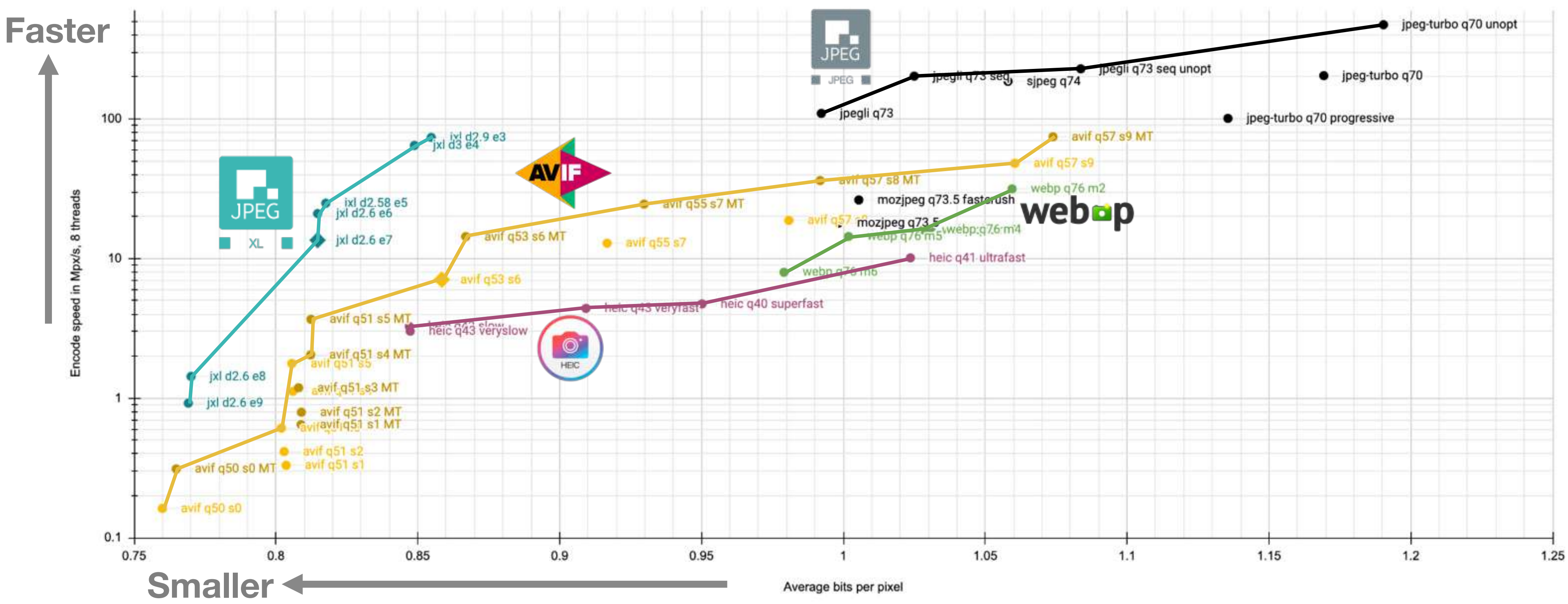
Performance (lossless, non-photo)



JPEG XL

Performance (lossy, web quality, photo)

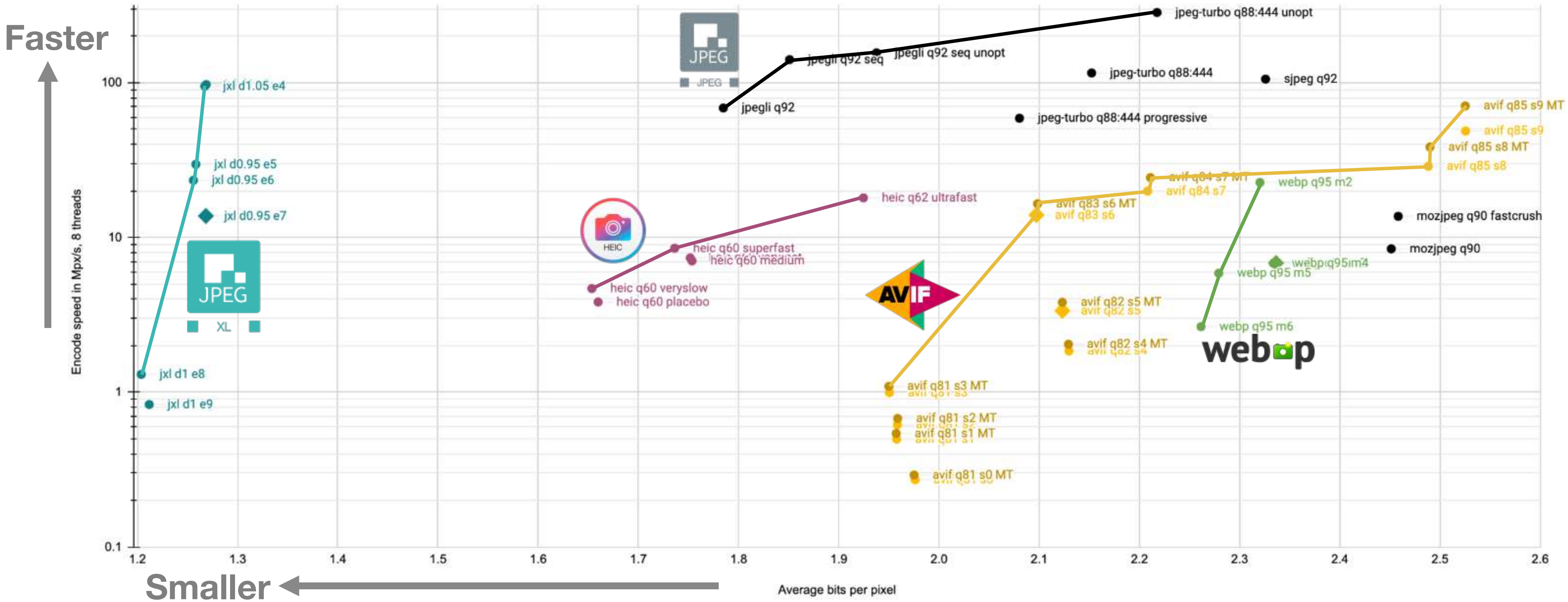
Web quality lossy compression (Daala test set, 49 images ~1Mpx each, avg SSIMULACRA2 = 70 ±1)



JPEG XL

Performance (lossy, high quality, photo)

High quality lossy compression (imagecompression.info, 8-bit, average image size 11 Mpx, avg SSIMULACRA2 = 85 ±0.5)



JPEG XL adoption

JPEG

JPEG

AI

JPEG AI scope

The JPEG AI scope is the creation of a learning-based image coding standard offering a single-stream, compact, compressed domain representation, targeting both human visualization, with significant compression efficiency improvement over image coding standards in common use at equivalent subjective quality, as well as effective performance for image processing and computer vision tasks, with the goal of supporting a royalty-free baseline

Applications & Use Cases

- Cloud storage
- Visual surveillance
- Autonomous vehicles and devices
- Image collection storage and management
- Live monitoring of visual data
- Media distribution
- 360° photo sharing

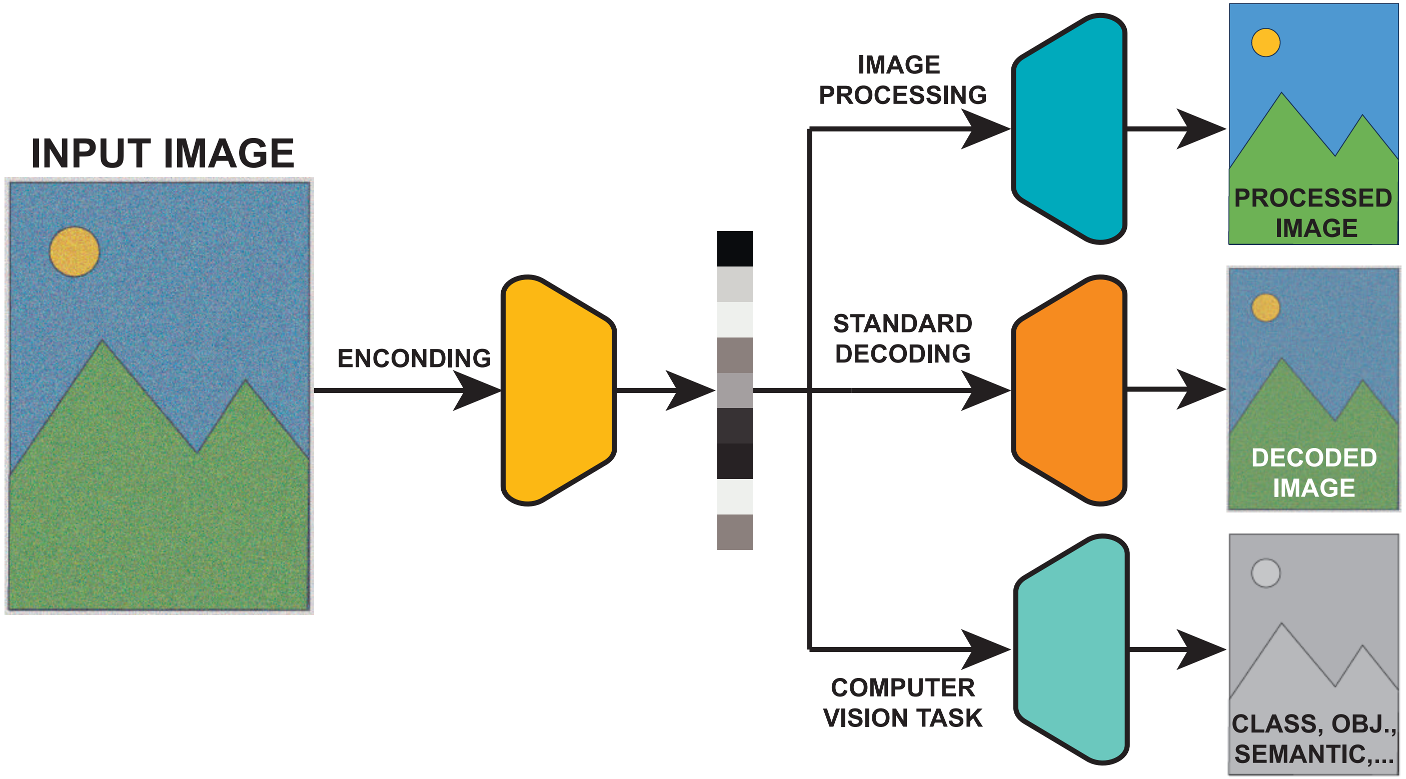
Application-driven Requirements

- **High coding efficiency** is important for many applications such as **cloud storage** or **media distribution**

- **Content understanding** is vital for many applications such as visual surveillance, autonomous vehicles, image collection management, etc.
  - Objects may need to be recognized
  - Images may need to be classified for organization purposes
  - Actions or events may need to be recognized

- Content **consumed by humans** in many applications such as in media distribution
  - Noise can be reduced
  - Resolution can be increased
  - Colors can be corrected

JPEG AI Framework



JPEG AI roadmap

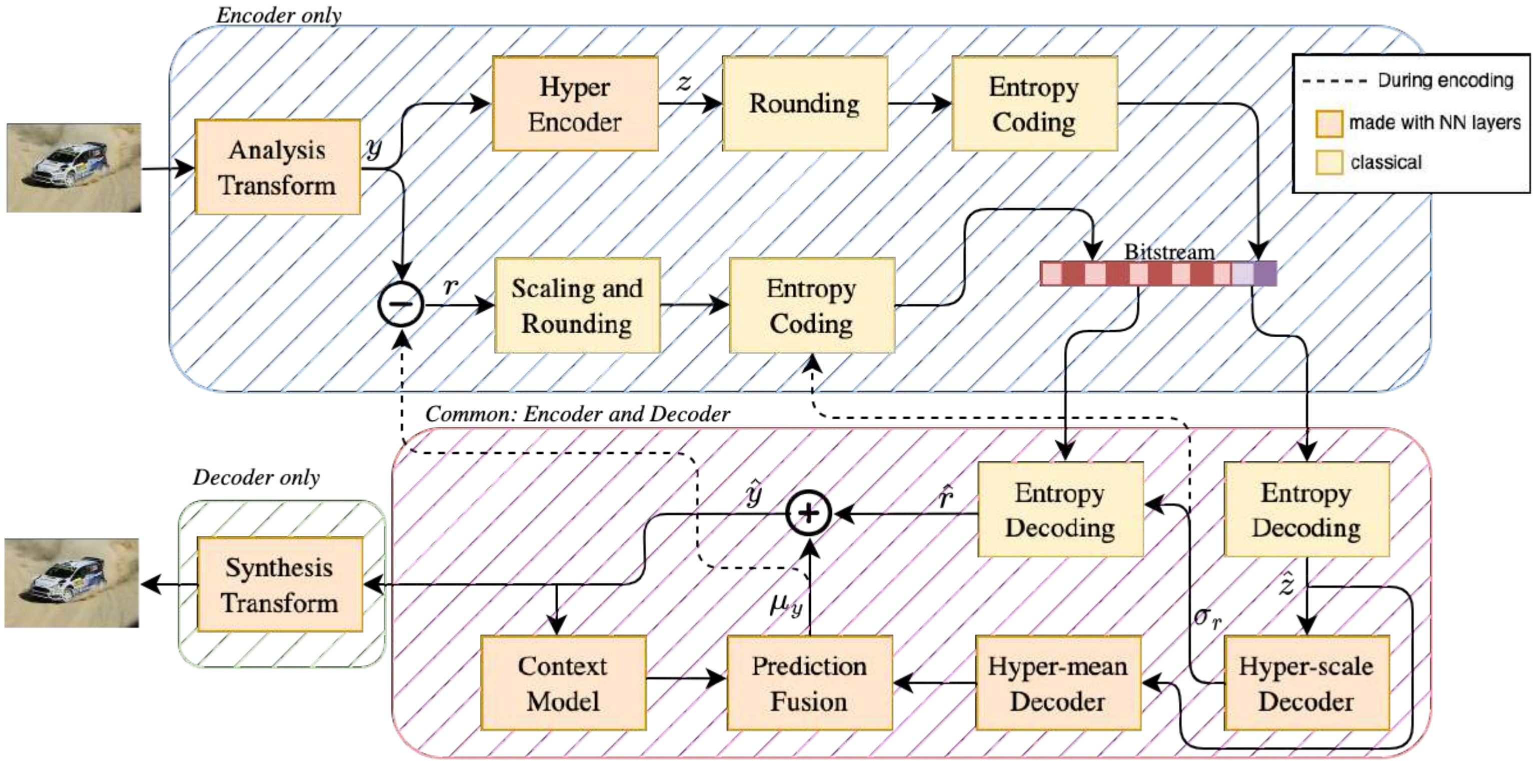
VERSION 1

- Version 1 addresses several (but not all) JPEG AI ‘core’ and ‘desirable’ requirements with emphasis on compression efficiency.

VERSION 2

- Version 2 will address/include:
  1. JPEG AI requirements not yet addressed in Version 1, e.g. processing and computer vision tasks
  2. Significantly improved solutions for JPEG AI requirements already addressed in Version 1, e.g. compression efficiency.

JPEG AI Architecture

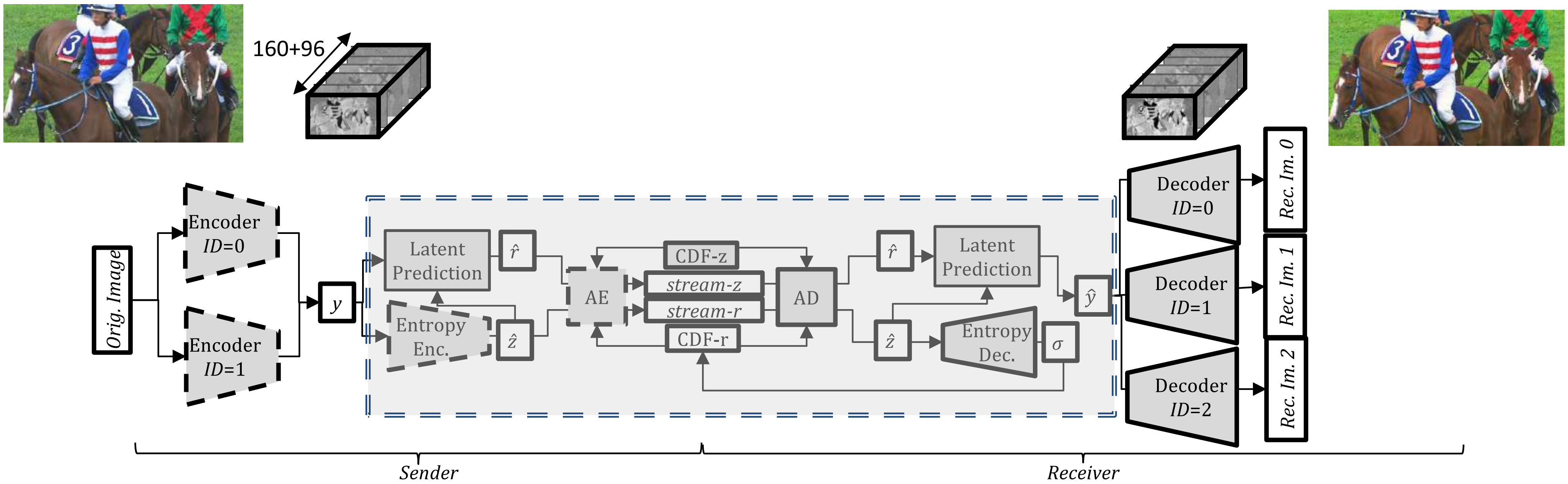


Addressing Complexity Issues

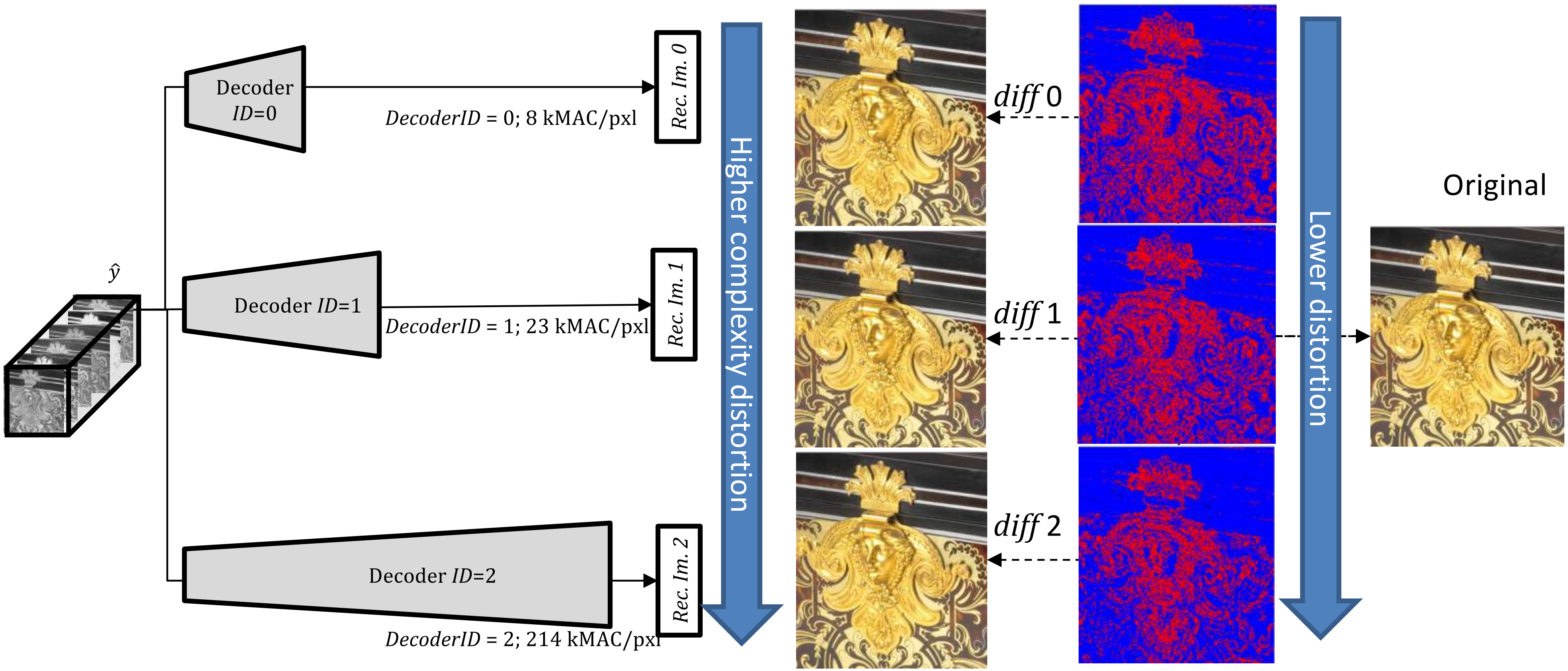
- The lightest operating points provides 10% compression gains (tools-off) over VVC Intra, at just 20 kMAC/pxl and 15% compression gains (tools-on) at approx. 30 kMAC/pxl
- The highest operating points provide 30% compression gains at approx. 200 kMAC/pxl

VS

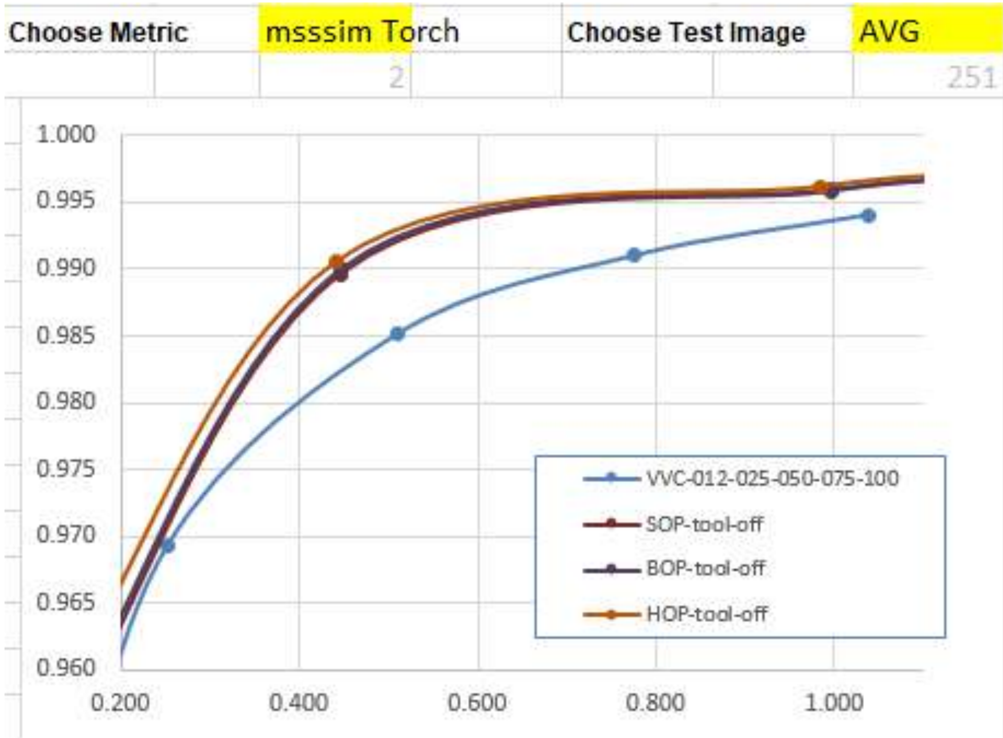
JPEG AI: Single Stream but Multiple Decoders

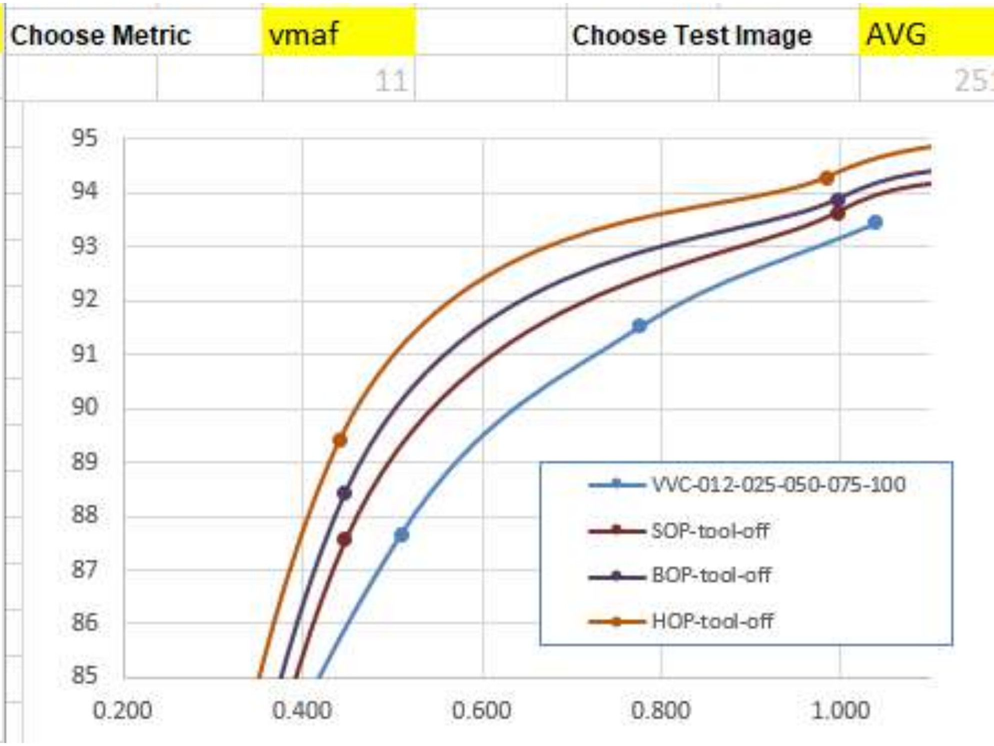


JPEG AI: Single Stream but Multiple Decoders



RD Performance





Overall Performance

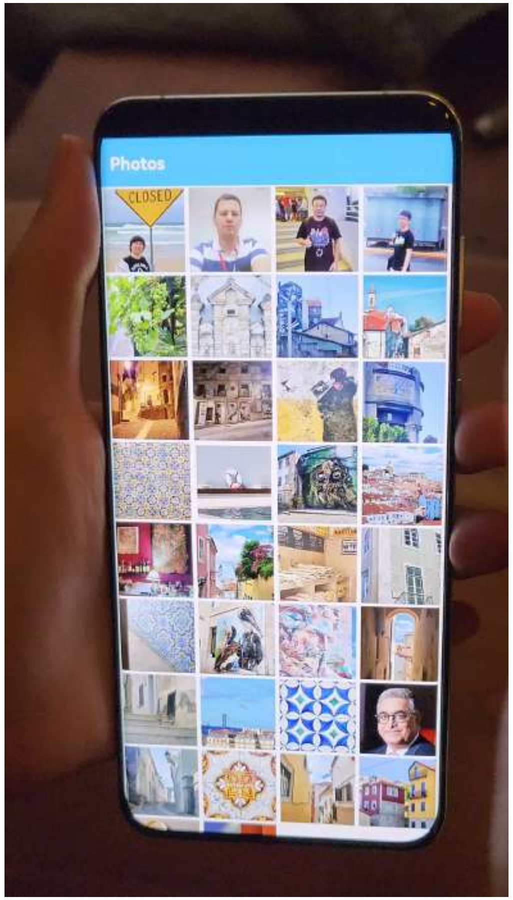
- SOP decoder as fast on CPU as VVC Intra
- BOP decoder is only twice slower on CPU compared to VVC Intra

Codec	8K Encoding, s
JPEG	5
HEVC / H.265	2689
VVC / H.266	18725
JPEG AI	5 (Enc0) or 20 (Enc1)

Test	BD-Rate AVG	Dec.			Enc.
		kMAC/pxl	*Time GPU, ×*	*Time CPU, ×*	*Time GPU, ×*
HEVC-SCC Intra	7.5%	-	0.8 (CPU)	0.8 (CPU)	0.8 (CPU)
VTM-11 Intra	0.0%	-	1 (CPU)	1 (CPU)	1 (CPU)
VM6.1-Enc0Dec0-tools-off	**-12.0%**	**8**	**0.36**	**1.05**	**0.0005**
VM6.1-Enc0Dec0-tools-on	-16.2%	14	0.41	2.4	0.0011
VM6.1-Enc0Dec1-tools-off	**-16.7%**	**23**	**0.38**	**2.1**	**0.0005**
VM6.1-Enc0Dec1-tools-on	-20.2%	28	0.41	3.3	0.0011
VM6.1-Enc1Dec2-tools-off	**-24.0%**	**212**	**0.61**	**214**	**0.0012**
VM6.1-Enc1Dec2-tools-on	-27.0%	215	0.64	215	0.0018

JPEG AI Smartphone Demos

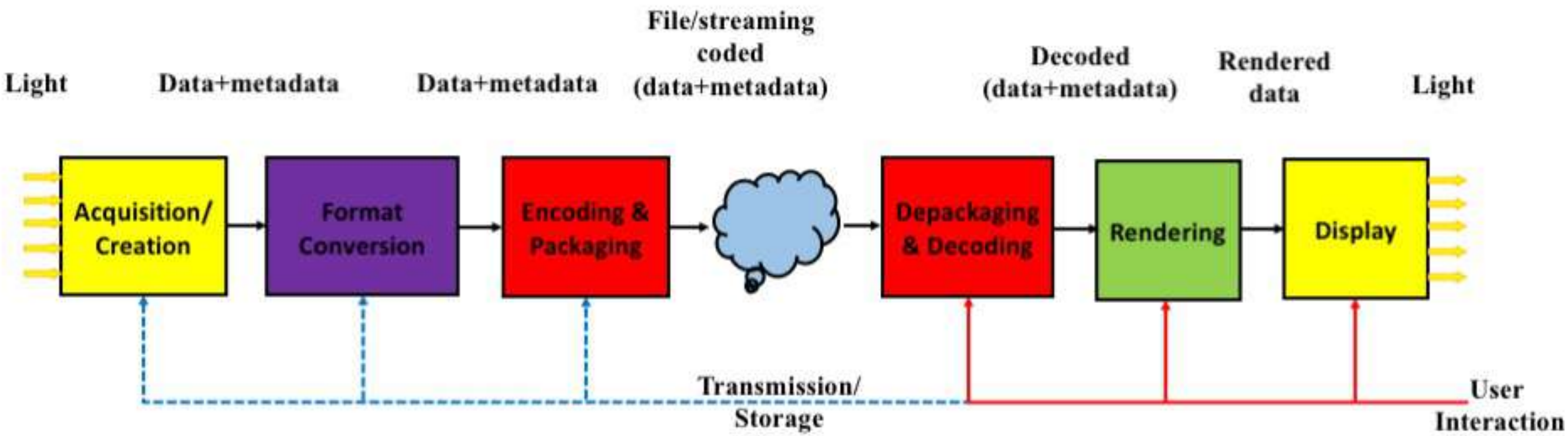
Huawei Mate50 Pro



Iphone 14 Pro Max

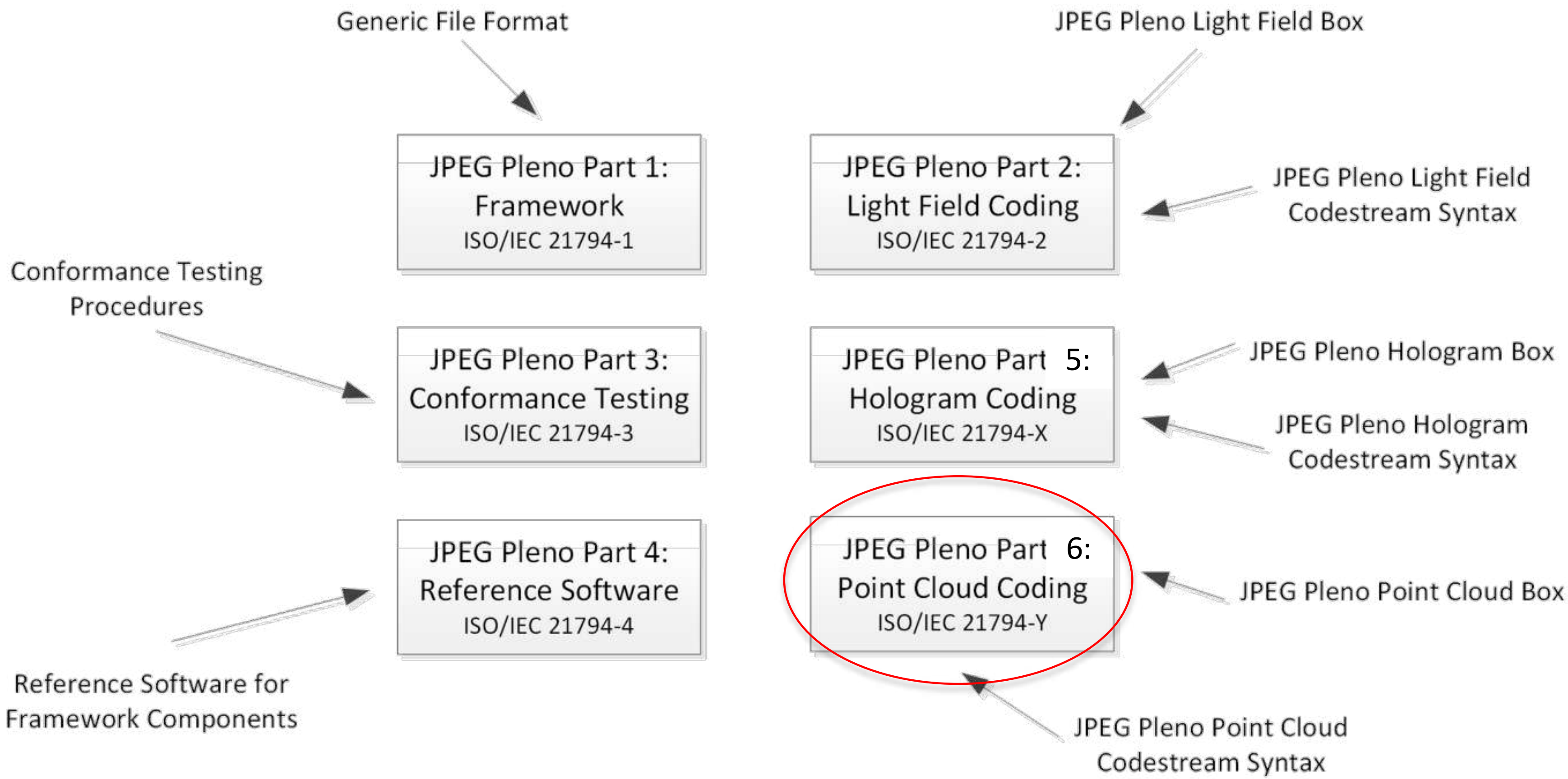
Point cloud

JPEG Pleno end-to-end processing chain



JPEG Pleno

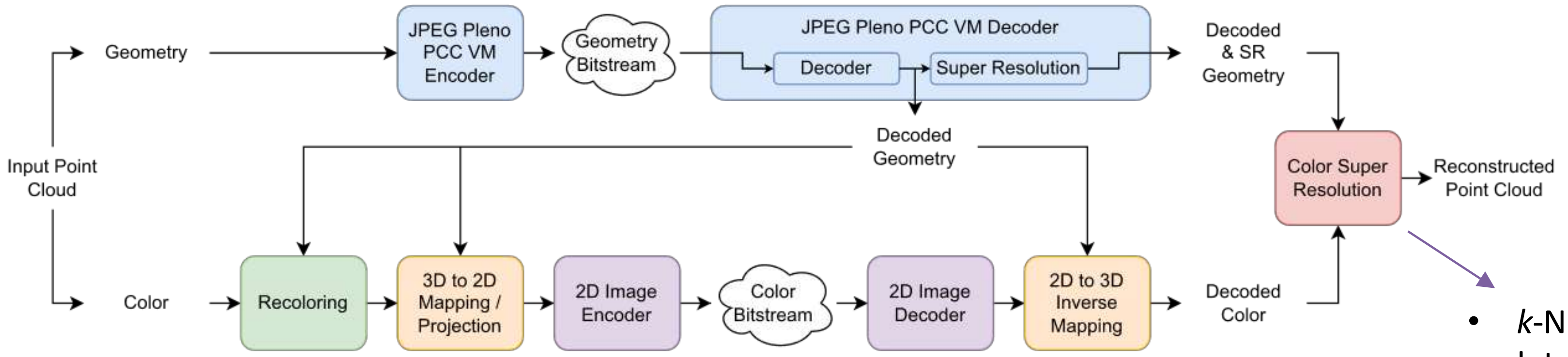
Framework



Scope of JPEG Pleno Point Cloud Coding

The scope of the JPEG Pleno Point Cloud activity is the creation of a **learning-based coding standard** for point clouds and associated attributes, offering **compact compressed domain representation,** **supporting** **advanced flexible data access functionalities**. This standard targets **both** **interactive human visualization**, with competitive compression efficiency compared to state of the art point cloud coding solutions in common use, **and** **effective performance for 3D processing and machine-related computer vision tasks**, and has the goal of supporting a **royalty-free baseline**.

JPEG's Point Cloud Coding Solution



- *k*-NN recoloring
- Interpolation
- DL-based

3D to 2D Color Projection: V-PCC Projection

Expands on the JPEG ecosystem of learning-based coding while taking advantage of the power of the emerging JPEG AI standard.

Key Features of JPEG Pleno Learning based Point Cloud Coding

- Flexible control of Color and Geometry Encoding Chains allowing for precise control over bitrate allocation to color and geometry components of point cloud
- Color coding pipeline leverages the strong coding performance of JPEG AI and fits into the JPEG learning-based coding ecosystem.
- Both the Geometry and Colour pipelines utilize deep learning-based super-resolution to increase the reconstructed quality at no additional rate cost.

JPEG Pleno timeline

Point cloud

Part	Title	WD	CD	DIS	FDIS	IS
1	JPEG Pleno: Framework	18/01	19/03	19/07	20/01	20/10
2	JPEG Pleno: Light Field Coding	18/04	19/01	19/07	20/04	21/04
3	JPEG Pleno: Conformance Testing	19/11	20/07	20/10	-	21/04
4	JPEG Pleno: Reference Software	19/11	20/07	20/10	21/07	22/04
5	JPEG Pleno: Holography	22/01	22/10	23/04	24/01	24/10
6	JPEG Pleno: Learning-based Point Cloud Coding	22/10	24/01	24/07	-	25/01

JPEG

JPEG

DNA

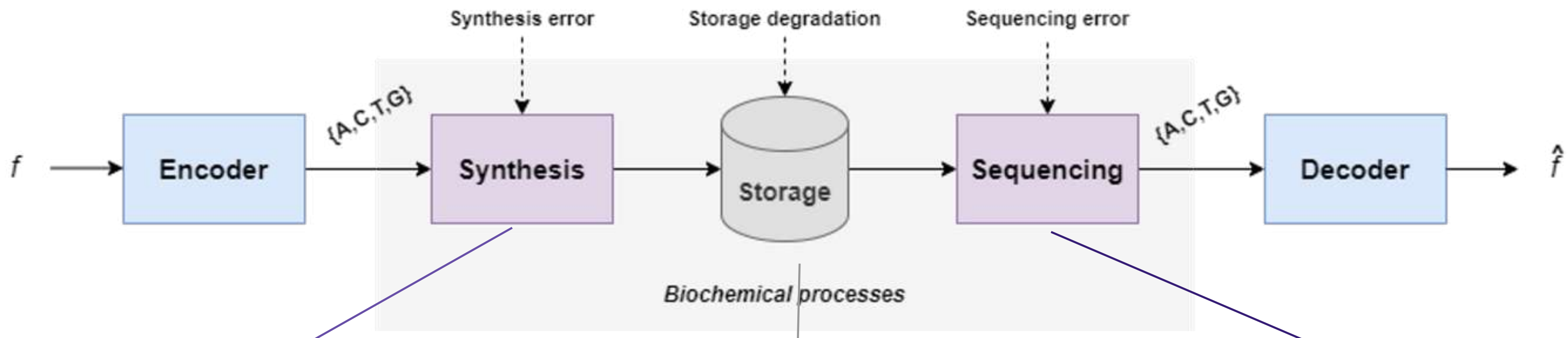
Why DNA data storage?

- DNA-based media storage is very interesting because:
  - Storage **density** seems to be extremely high, notably beyond any available storage technology
  - Storage is also extremely **stable**, in the order of thousands of years in good conditions, as demonstrated by the complete genome sequencing of a fossil horse that lived more than 500’000 years ago
  - Does not require much **energy**, i.e. ecologically friendly
- DNA-based storage may be a **very powerful alternative to the current data-storage solutions** which have rather serious limitations, notably in terms of storage capacity, duration and energy consumption.

JPEG DNA scope

The scope of JPEG DNA is the creation of a standard for **efficient coding of images that considers biochemical constraints** and offers **robustness to noise introduced by the different stages of the storage process that is based on DNA synthetic polymers.**

A biologically constrained problem



– Length limited to 300 nts
– Errors increase exponentially for longer oligos

– DNA is prone to chemical decay if not stored under optimal conditions.

– Main source of errors
– Higher error if: homopolymers, patterns and unbalanced %GC

Applications and use cases

- Long Term Media Archives and Cultural Heritage Preservation
- Social Networks Cold Media Storage
- Preservation of Medical Images
- Preservation of Large-scale Repositories of Biomedical Data: Beyond Local Data Storage
- DNA Coding for Traceability

JPEG DNA Timeline

- 2023 January: Draft Call for Proposals
- 2023 April: Final Call for Proposals
- 2023 October: Evaluation of proposals
- 2024 April: First Working Draft (WD)
- 2025 January: Committee Draft (CD)
- 2025 July: Draft International Standard (DIS)
- 2026 International Standard (IS)

Thanks for your attention!

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