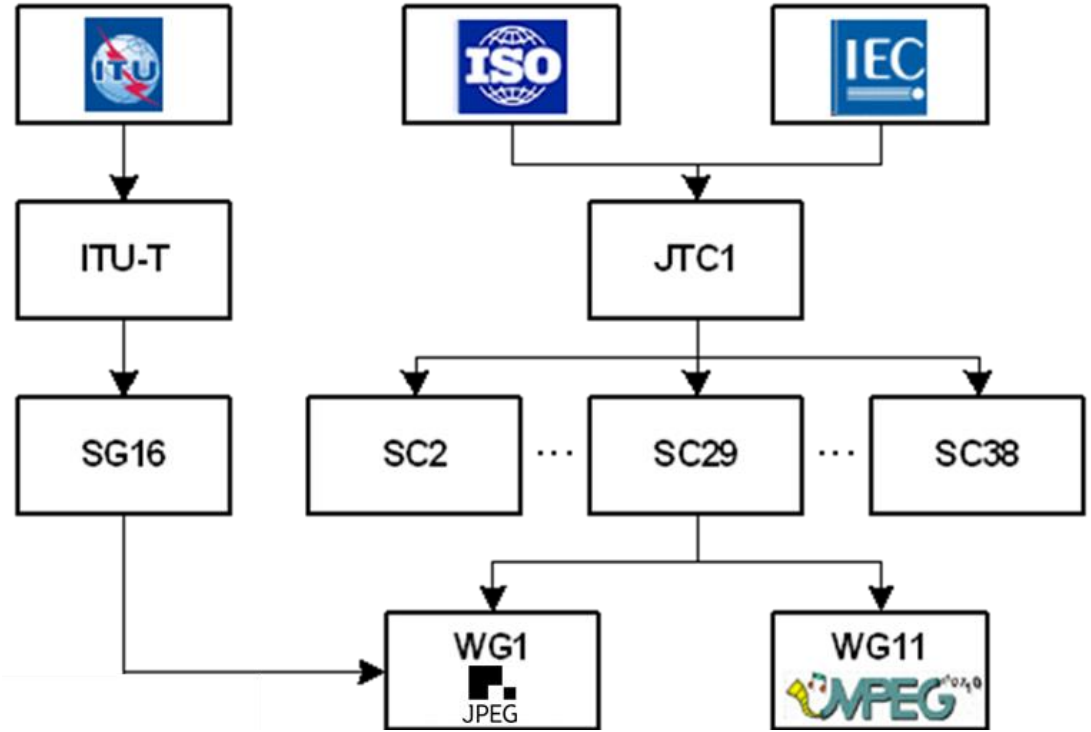
JPEG XL
Next-generation image coding

Touradj Ebrahimi

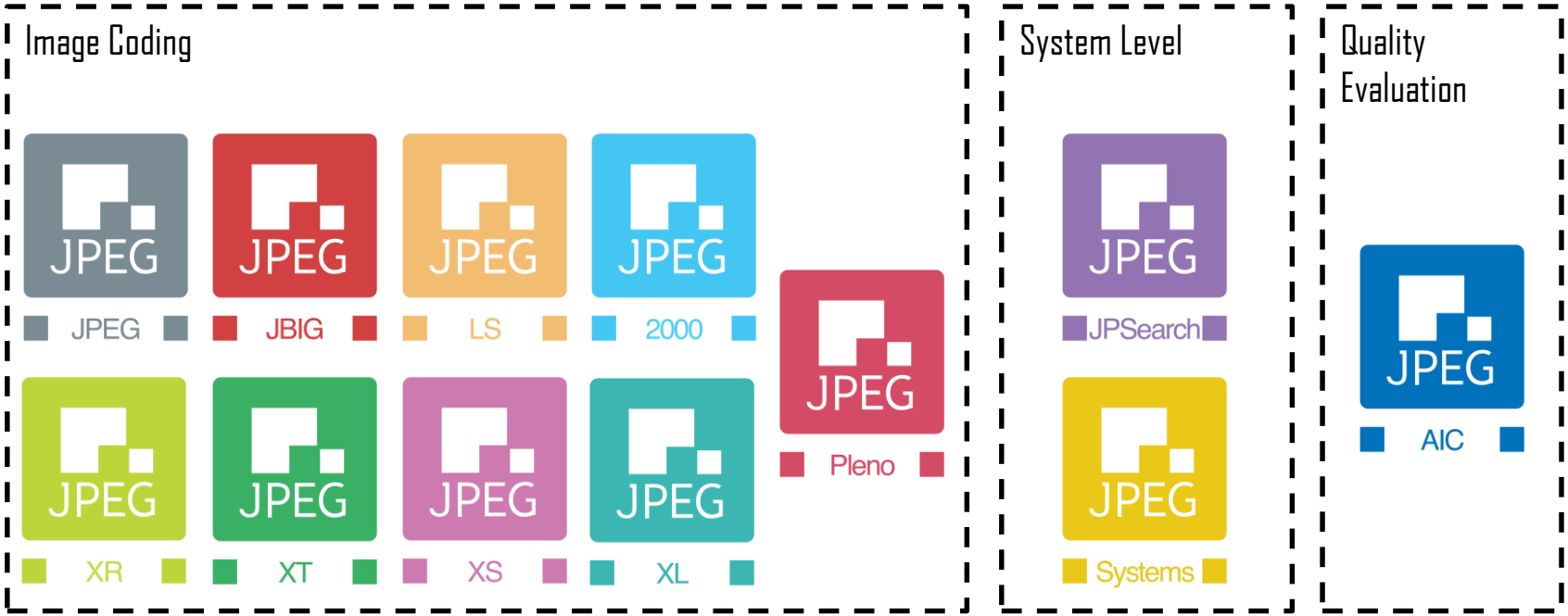
JPEG Convenor

What is JPEG?

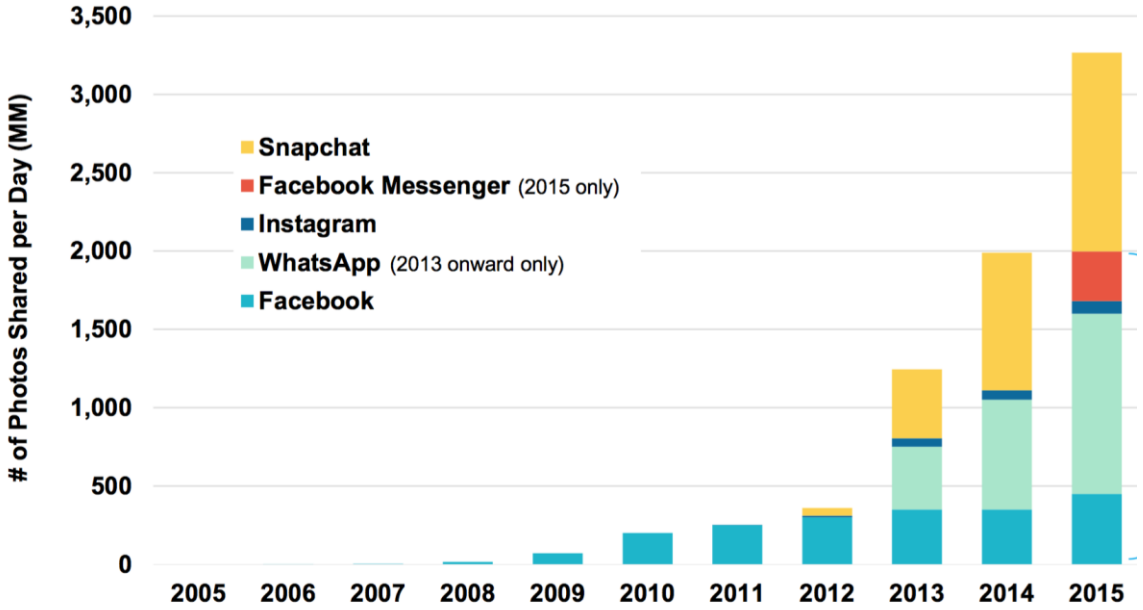


- Joint Photographic Experts Group
  - ISO/IEC
  - ITU-T
- Informally known as JPEG
  - WG1 in official communications

JPEG Family of Standards



JPEG ecosystem revolutionized digital photography



Source: KPCB Internet Trends 2016 (June 2016).

1995-96 Technology and Engineering Emmy award (together with MPEG-2)

2019 Engineering Emmy award

JPEG

JPEG

JPEG (ISO/IEC 10918)

Part 1: Requirements and guidelines

Specifies the core coding system, consisting of the well-known Huffman-coded DCT based lossy image format, but also including the arithmetic coding option, lossless coding and hierarchical coding.

Part 2: Compliance testing

Specifies conformance testing, and as such provides test procedures and test data to test JPEG encoders and decoders for conformance.

Part 3: Extensions

Specifies various extensions of the JPEG format, as such spatially variable quantization, tiling, selective refinement and the SPIFF file format.

Part 4: Registration authorities

Registers known application markers, SPIFF tags profiles, compression types and registration authorities.

Part 5: File Interchange Format

Specifies the JPEG File Interchange Format (JFIF) which includes the chroma upsampling and YCbCr to RGB transformation.

Part 6: Application to printing systems

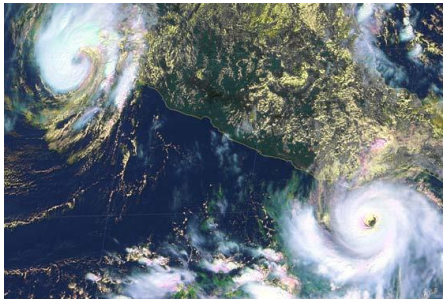
Specifies markers that refine the colour space interpretation of JPEG codestreams, such as to enable the embedding of ICC profiles and to allow the encoding in the CMYK colour model.

Part 7: Reference Software

Provides JPEG Reference Software implementations.

JPEG 2000

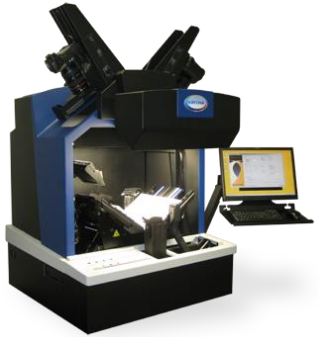
DICOM
Digital Imaging and Communications in Medicine



DCI
Digital Cinema Initiatives, LLC

VSF
VIDEO SERVICES FORUM

PDF/A



2015 Technology and Engineering
Emmy award (JPEG 2000 interoperability)

JPEG
2000

JPEG 2000 (ISO/IEC 15444)

Part 1, Core coding system

Part 1 defines the core of JPEG 2000: the syntax of a JPEG 2000 codestream and the necessary steps involved in decoding JPEG 2000 images, with informative guidance for encoders.
Part 1 also defines a basic file format called JP2, which allows metadata such as color space information and IP rights to be provided with a JPEG 2000 codestream.

Part 2, Extensions

Part 2 defines codestream and file format extensions to Coding technology extensions include: multi-component transformations; more flexible wavelet tranform kernels and decomposition structures; alternate quantization schemes; and non-linear point transforms. The Part 2 JPX file format, extends the Part 1 JP2 file format to allow: more comprehensive color space descriptions and HDR sample representations; multiple codestreams; composition, cropping, geometric transforms and rich animations; descriptive metadata; and a rich metadata set for photographic imagery.

Part 3, Motion JPEG 2000 (MJ2 or MJP2)

Part 3 defines a file format for motion sequences of JPEG 2000 images, where each image is coded independently within a JPEG 2000 codestream.

Part 4, Conformance

Part 4 specifies test procedures for both encoding and decoding processes defined in JPEG 2000 Part 1, including the definition of a set of decoder compliance classes. The Part 4 test files include both bare codestreams and JP2 files.

Part 5, Reference software

Part 5 consists of two source code packages that implement Part 1. The implementations were developed alongside Part 1 and were used to test it. One is written in C and the other in Java. They are both available under open-source licenses.

Part 6, Compound image file format

Part 6 defines the JPM file format for multi-page document imaging, which uses the Mixed Raster Content (MRC) model of ISO/IEC 16485. JPM is an extension of the JP2 file format defined in Part 1. Although it is a member of the JPEG 2000 family, it supports the use of many other coding or compression technologies, including JBIG2 and JPEG.

l defines tools and
e the efficient
000 imagery over
ss network. More
1 extends the
e coding system
h mechanisms for
correction. These
ward compatible:
ment Part 1 are
nsions defined in

Part 12, ISO Base Media File Format

Part 12 has common text with Part 12 of the MPEG-4 standard, ISO/IEC 14496-12. It is a joint JPEG and MPEG initiative to create a base file format for future applications.
The format is a general format for timed sequences of media data. It uses the same underlying architecture as Apple's QuickTime file format and the JPEG 2000 file format.

Part 13, Entry-level Encoder

Part 13 define an entry-level encoder implementation of Part 1.

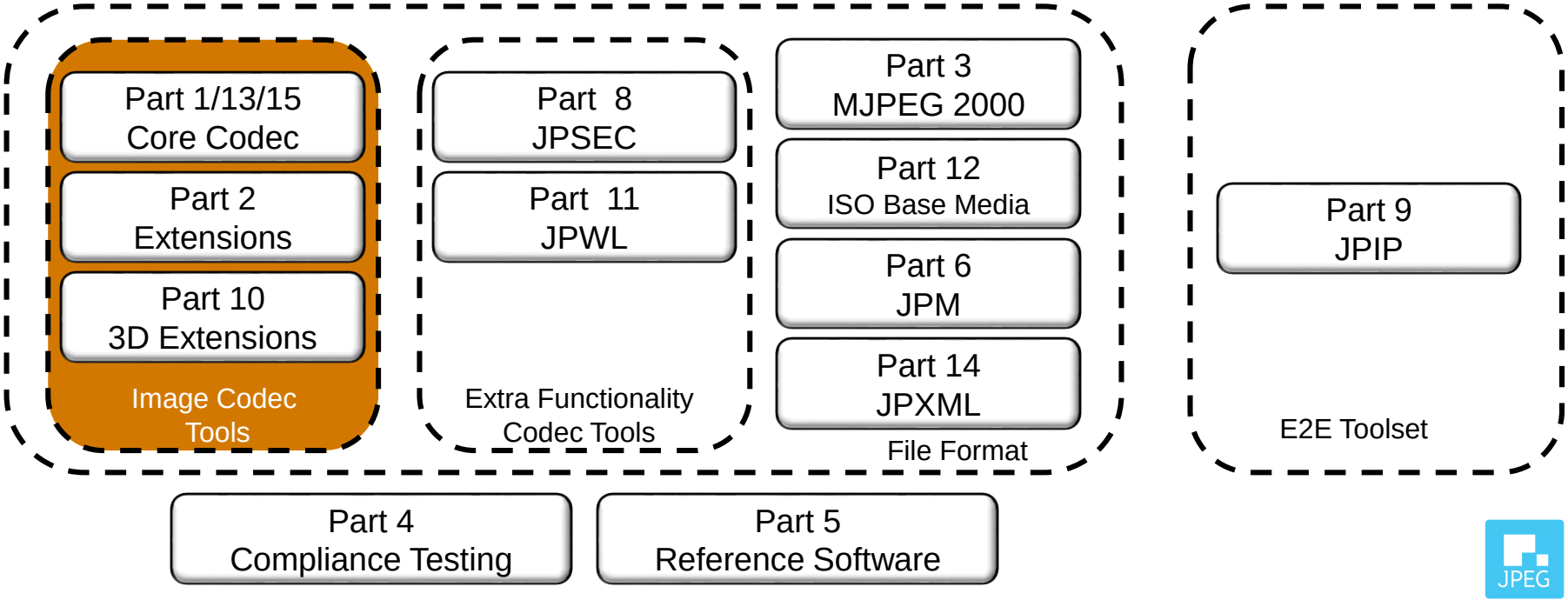
ML representation
ormat and marker
referring methods
EG 2000 image.

Part 15, HTJ2K (Under-development)

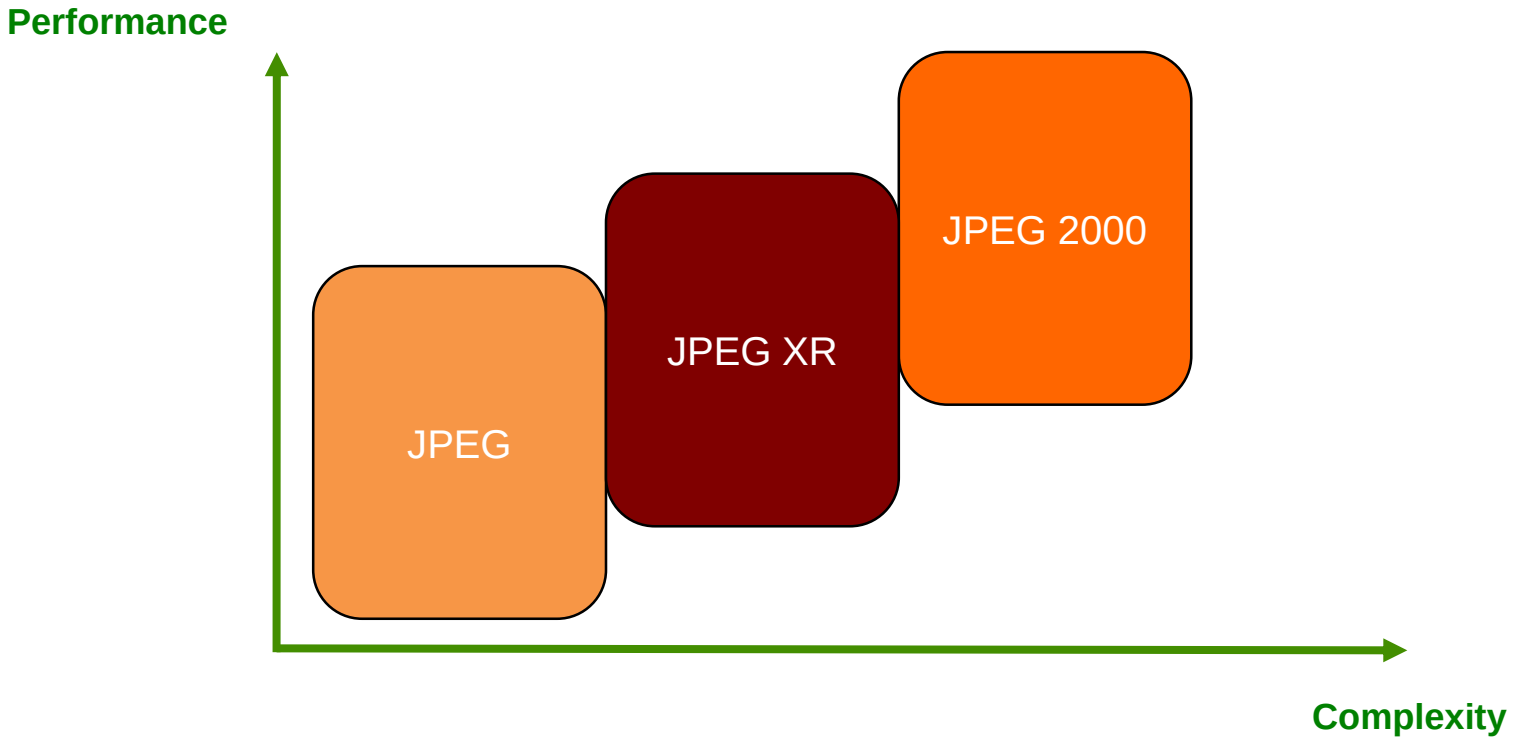
Part 15, which is under-development, specifies an alternate block coding algorithm that can be used in place of the existing block coding algorithm specified in Part 1. The alternate block coding algorithm is intended to offer a ten-fold increase in throughput at the expense of slightly reduced coding efficiency, while allowing mathematically lossless transcoding to/from codestreams that use the Part 1 block coding algorithm, and preserving Part 1 codestream syntax and features.

JPEG 2000

JPEG 2000 framework



JPEG XR (ISO/IEC 29199)



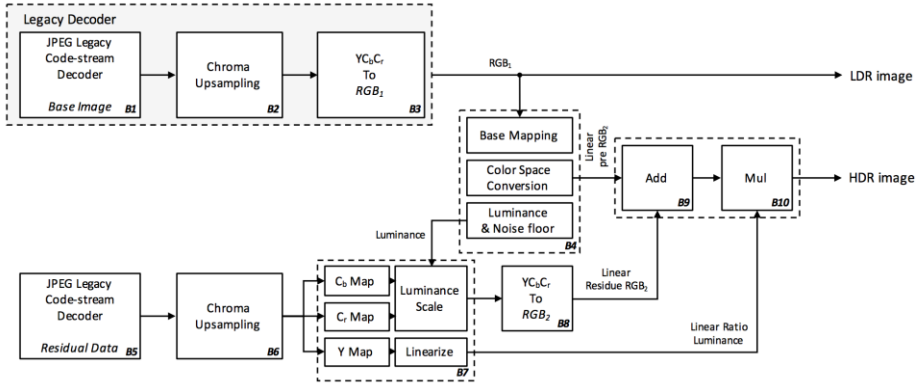
JPEG XR (ISO/IEC 29199)

JPEG XT backward compatible compression

- Emphasis on backward computability with JPEG legacy

JPEG XT design principles

- Two-layer coding, with **base layer a legacy JPEG coded LDR** and enhancement layer with additional features
  - HDR coding
  - Lossless coding
  - Alpha channel coding
- Enhancement layer uses as much as possible JPEG Legacy coding tools



JPEG XT (ISO/IEC 18477)

Part 1, Core coding system

JPEG XT Part 1 specifies the base technology, and specifies as such the core JPEG as it is used nowadays, namely as a selection of features from ISO/IEC 10918-1, 10918-5 and 10918-6. Part 1 defines as what is commonly understood as JPEG today.

Part 2, Coding of high dynamic range images

JPEG XT Part 2 is a backwards compatible extension of JPEG towards high-dynamic range photography using a legacy text-based encoding technology for its metadata.

Part 3, Box file format

JPEG XT Part 3 specifies an extensible boxed-based file format all following and future extensions of JPEG will be based on. The format specified in Part 3 is itself compatible to JFIF, ISO/IEC 10918-5, and thus can be read by all existing implementations.

Part 4, Conformance testing

JPEG XT Part 4 defines conformance testing of JPEG XT.

Part 5, Reference software

JPEG XT Part 5 provides the JPEG XT reference software.

Part 6, IDR Integer coding

JPEG XT Part 6 defines extensions of JPEG for backwards compatible coding of integer samples between 9 and 16 bit precision. It uses the file format specified in Part 3.

Part 7, HDR floating-point coding

JPEG XT Part 7 uses the mechanism of Part 3 to extend JPEG for coding of HDR images, i.e. images consisting of floating point samples. It is a super-set of both Part 2 and Part 3 and offers additional coding tools addressing needs of low-complexity or hardware implementations.

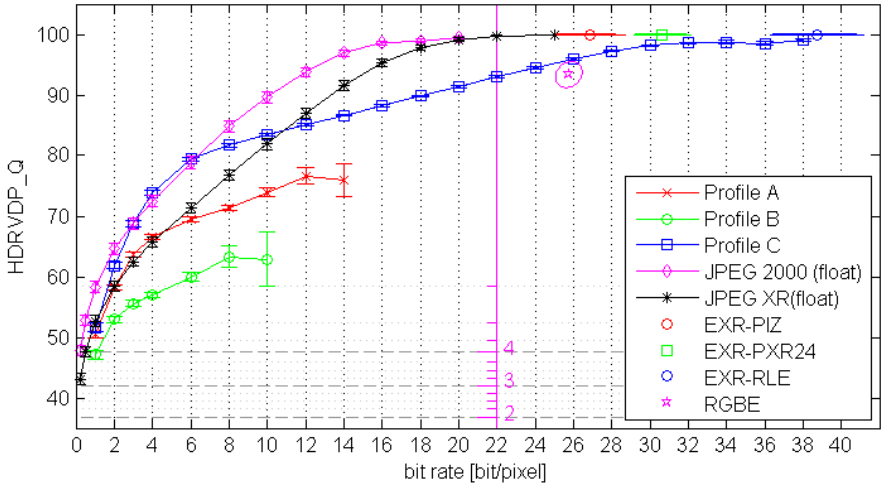
Part 8, Lossless and near-lossless coding

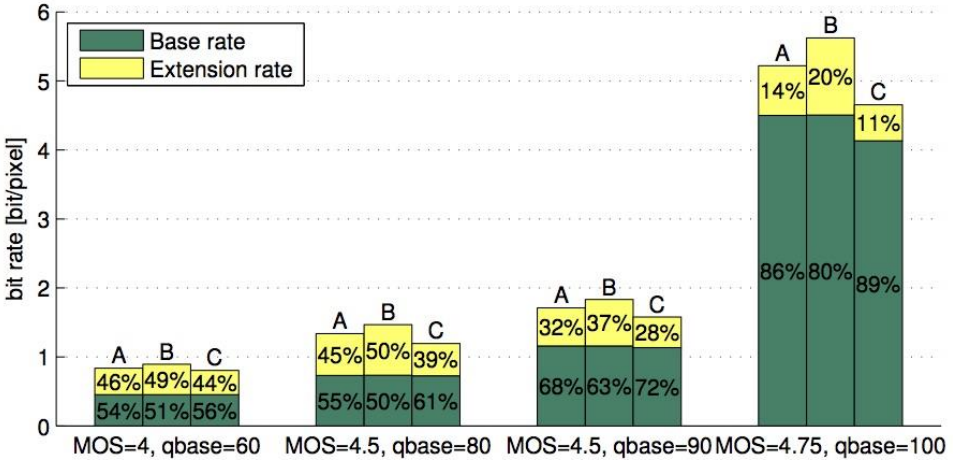
JPEG XT Part 8 defines lossless coding mechanisms for integer and floating point samples. It is an extension of Part 6 and Part 7, allowing for scalable lossy to lossless compression.

Part 9, Alpha channel coding

JPEG XT Part 9 allows the lossy and lossless representation of alpha channels, thus enabling the coding of transparency information and conding of arbitrarily shaped images.

JPEG XT (ISO/IEC 18477)





JPEG XS (ISO/IEC 21122)

Part 1: Core coding system

JPEG XS Part 1 (ISO/IEC 21122-1) normatively defines how a compressed JPEG XS codestream can be transformed into a decoded image in a bit exact manner. Moreover, it informatively explains the key algorithms enabling an encoder to generate a JPEG XS codestream.

Part 2: Profiles and buffer models

JPEG XS Part 2 (ISO/IEC 21122-2) ensures interoperability between different implementations by specifying typical codestream parameterizations and properties. This allows deriving the hardware and software requirements for different purposes such as high compression ratios, low memory or low logic implementations. Moreover, implementation guidelines inform about how to achieve low latency implementations.

Part 3: Transport and container

JPEG XS Part 3 (ISO/IEC 21122-3) defines how to embed a JPEG XS codestream into a more descriptive file format. Moreover, it contains all definitions that are necessary to transport a JPEG XS codestream by means of a transmission channel using existing transmission protocols defined by different standardization bodies.

Part 4, Conformance testing

JPEG XS Part 4 defines conformance testing of JPEG XS.

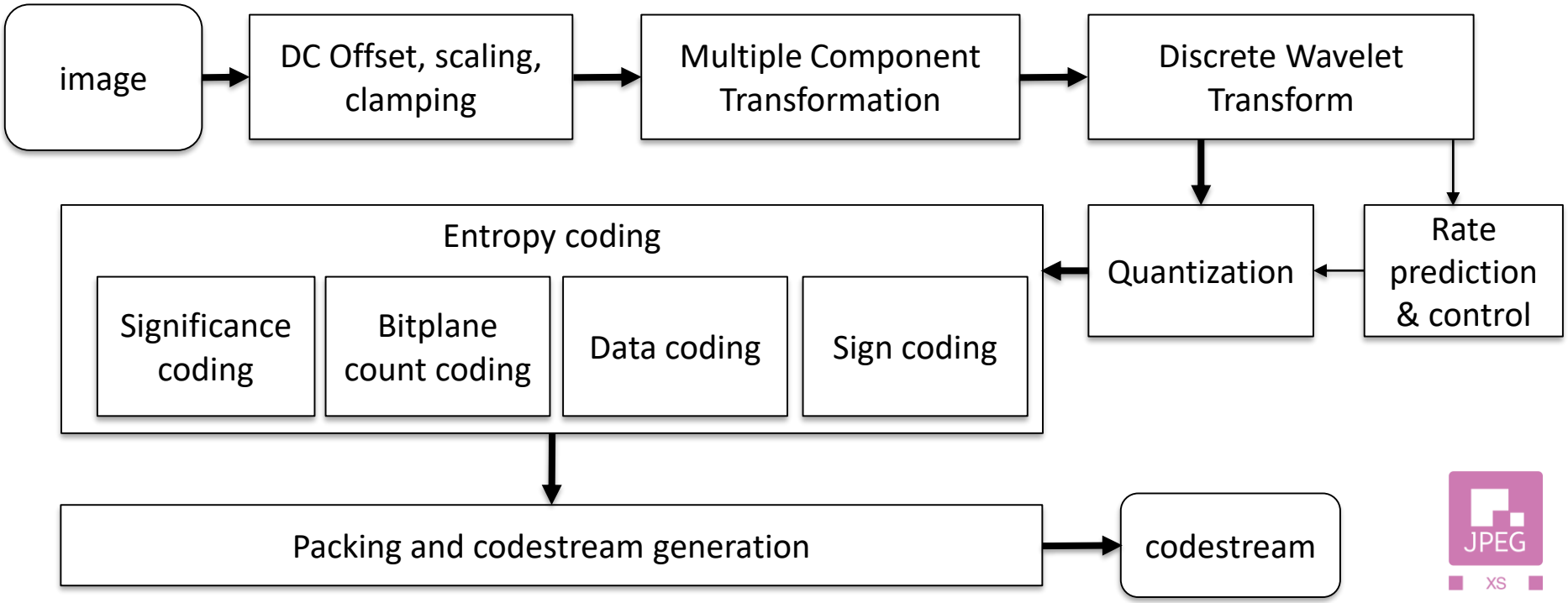
Part 5, Reference software

JPEG XS Part 5 provides the JPEG XS reference software.

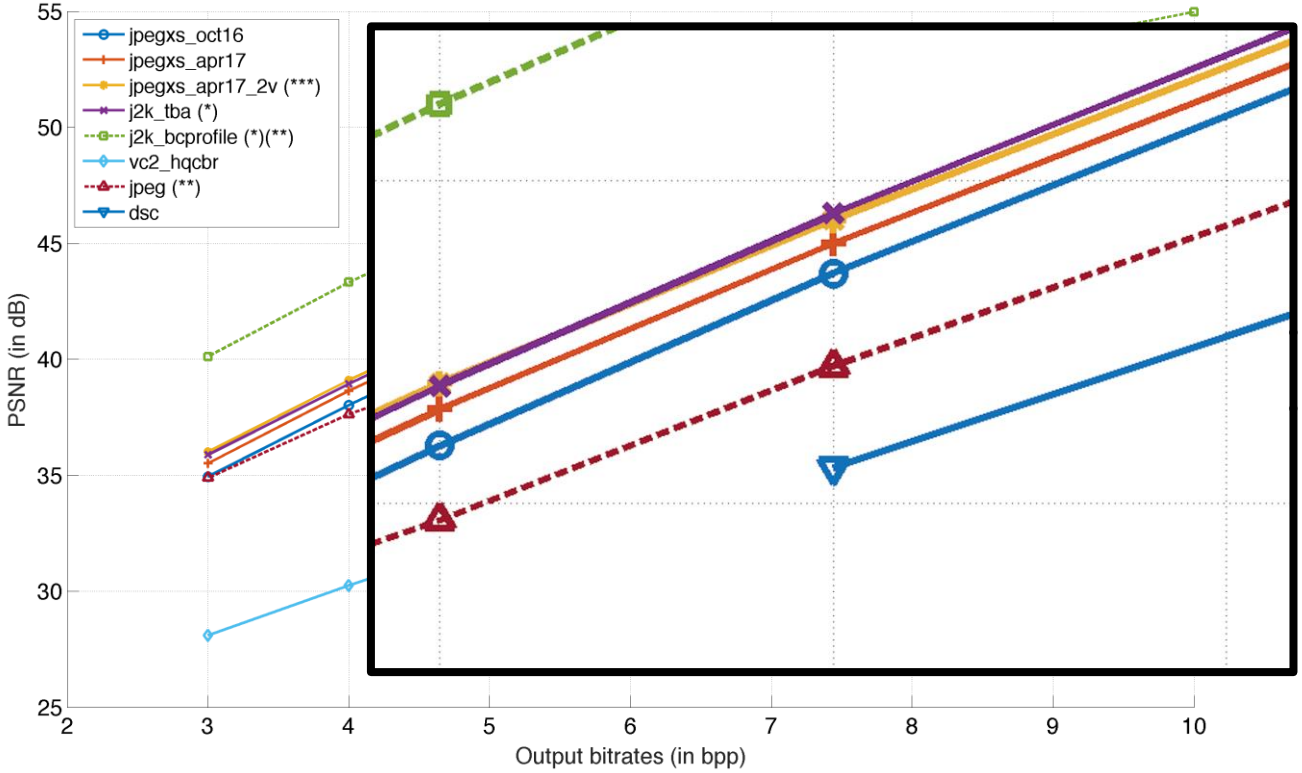
JPEG XS Light weight / Low Latency Image Coding

- Transparent quality
- Low complexity
- Low latency
- Modest compression

JPEG XS coding



Objective evaluations: single generation



JPEG XS outperforms VC-2 & DSC

JPEG XS outperforms JPEG

J2K Broadcast significantly better

JPEG XS and J2K tile-based allocation very close

Compared to Oct16:

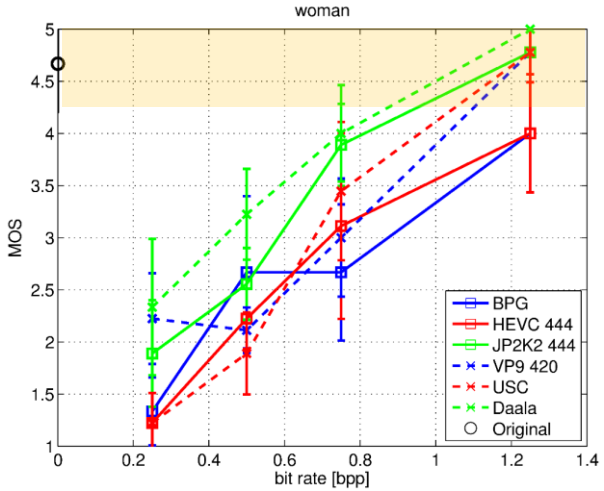
- Apr17: +0.45 dB
- Apr17_2V: +0.8 dB

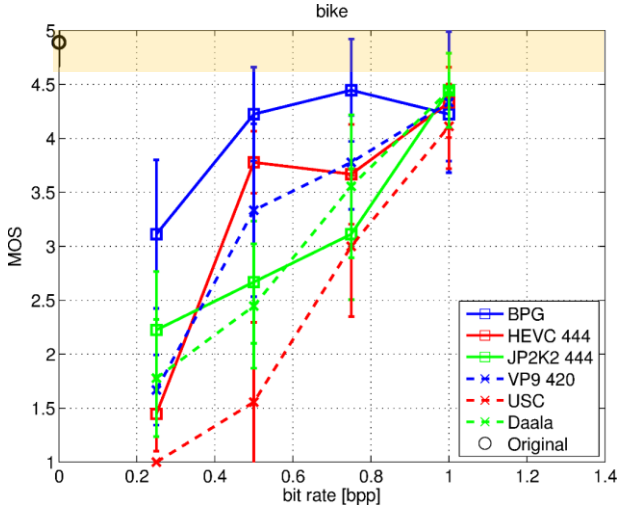
Advanced Image Coding (AIC)

- Advanced Image Coding
  - Part 1: Guidelines for codec evaluation
  - Part 2: Evaluation procedure for assessing visually lossless coding
  - Part 2 AMD1: Evaluation of high dynamic range content
  - Part 2 AMD2: Evaluation of image sequences
- Call for information issued in February 2015 to receive information on next generation still image compression with superior compression efficiency, as well as other useful features needed in future multimedia applications
- PCS 2015 Feature Event - Evaluation of current and future image compression technologies
- ICIP 2016 Image Compression Grand Challenge - Evaluation of innovative ideas for image compression technologies when compared to existing standards.

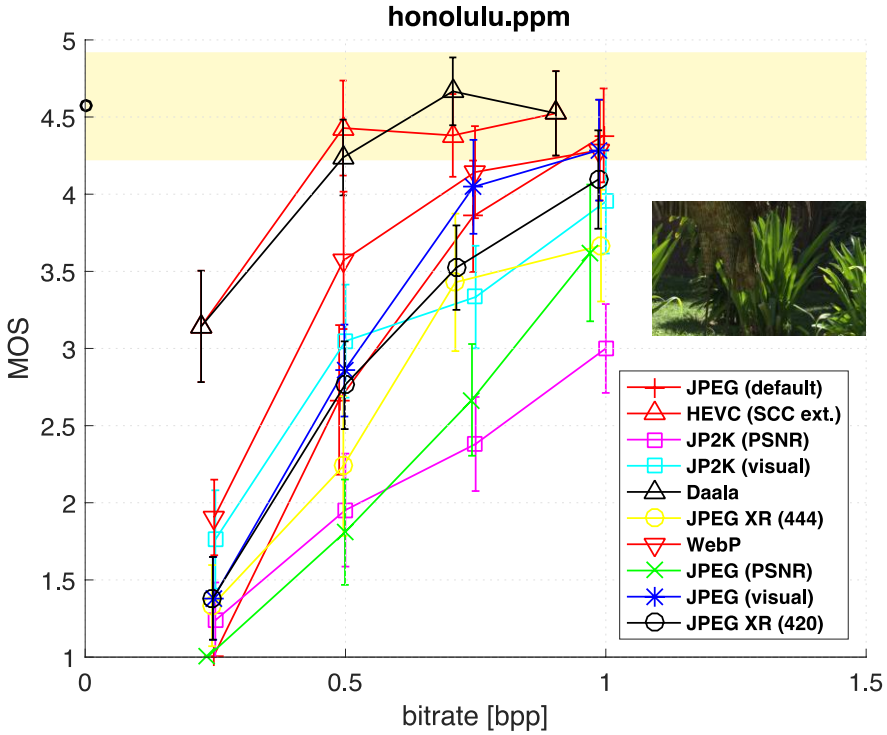
JPEG AIC

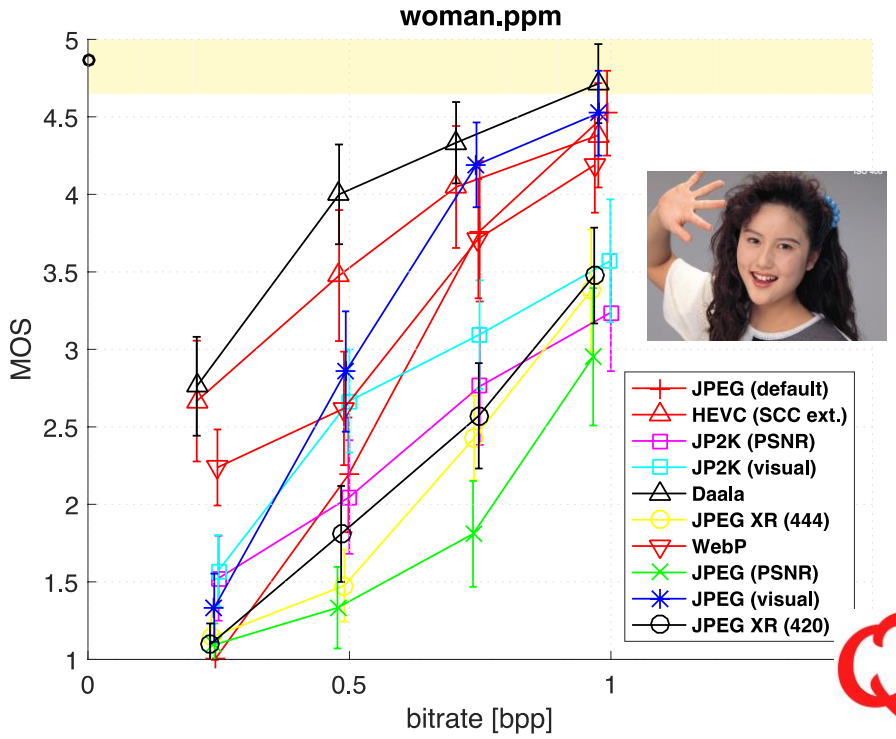
PCS 2015 image compression grand challenge





ICIP2016 GC subjective evaluation results





JPEG XL

Standardize a new image coding format that:

- Offers state-of-the-art compression efficiency
- Offers support for low-end and high-end imaging applications
- Has the potential to replace JPEG (ISO/IEC 10918)
- Can be royalty free

JPEG XL

With a good JPEG encoder like mozjpeg the (de facto) JPEG standard is still quite good!

BUT… it has **limitations**:

- Only lossy
- Bad for non-photographs (sharp edges, text)
- No alpha channel (transparency)
- Only 8-bit (problem for wide-gamut)
- No animation ⟶ This is why GIF is still around
- Not quite state-of-the-art entropy coding (Huffman)
- At lower bitrates: obvious compression artifacts (blockiness, color banding, ringing, DCT noise)

} Use PNG instead

JPEG XL

There have been many attempts to replace JPEG

- JPEG 2000
- JPEG XR
- JPEG XT
- WebP
- BPG
- HEIF (HEIC)
- AVIF

} Video codecs used as image codec

So far, none of them has really succeeded (yet)
(although some of them have had some success)

JPEG XL

Modest compression

Limitations
(8 bit, 4:2:0)

No progressive, only sequential

Complexity

Patent
mess

JPEG

NEWS & PRESS

Next-Generation Image Compression (JPEG XL) Final Call for Proposals

April 23, 2018

The JPEG Committee has launched the Next-Generation Image Compression activity, also referred to as JPEG XL. This activity aims to develop a standard for image compression that offers substantially better compression efficiency than existing image formats (e.g. >60% over JPEG-1), along with features desirable for web distribution and efficient compression of high-quality images.

The Next-Generation Image Compression activity has produced a final Call for Proposals, available in this document. Additional information on the CfP released at the 80th JPEG meeting in Berlin (July 2018) is available here.

To stay posted on the action plan for JPEG XL, please regularly consult our website at jpeg.org and/or subscribe to our e-mail reflector.

- proposal 1
- proposal 2
- proposal 3
- proposal 4
- proposal 5
- proposal 6
- proposal 7

JPEG XL

$\geq$

Google

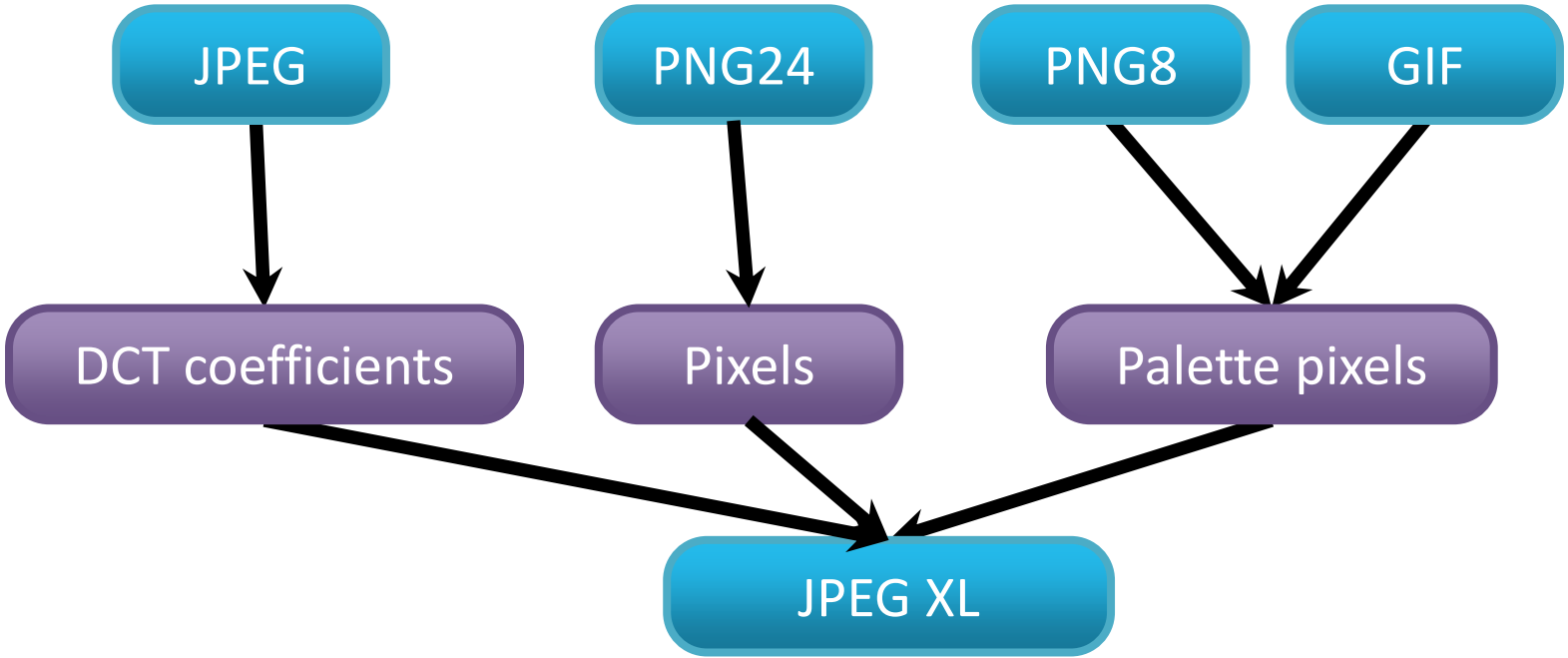
Pik Image Compression

Alexander Rhatushnyak, Evgenii Kliuchnikov, Jan Wassenberg, Jeffrey Lim, Jyrki Alakuijala, Krzysztof Potempa, Lode Vandevenne, Renata Khasanova, Robert Obryk, Sami Boukortt, Thomas Fischbacher, Zoltan Szabadka

+

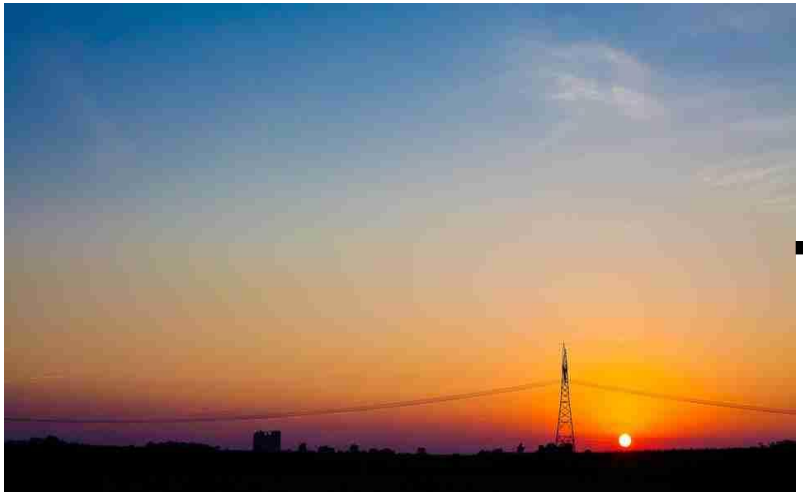
Cloudinary

Legacy image format friendly



No additional loss, always smaller than original!

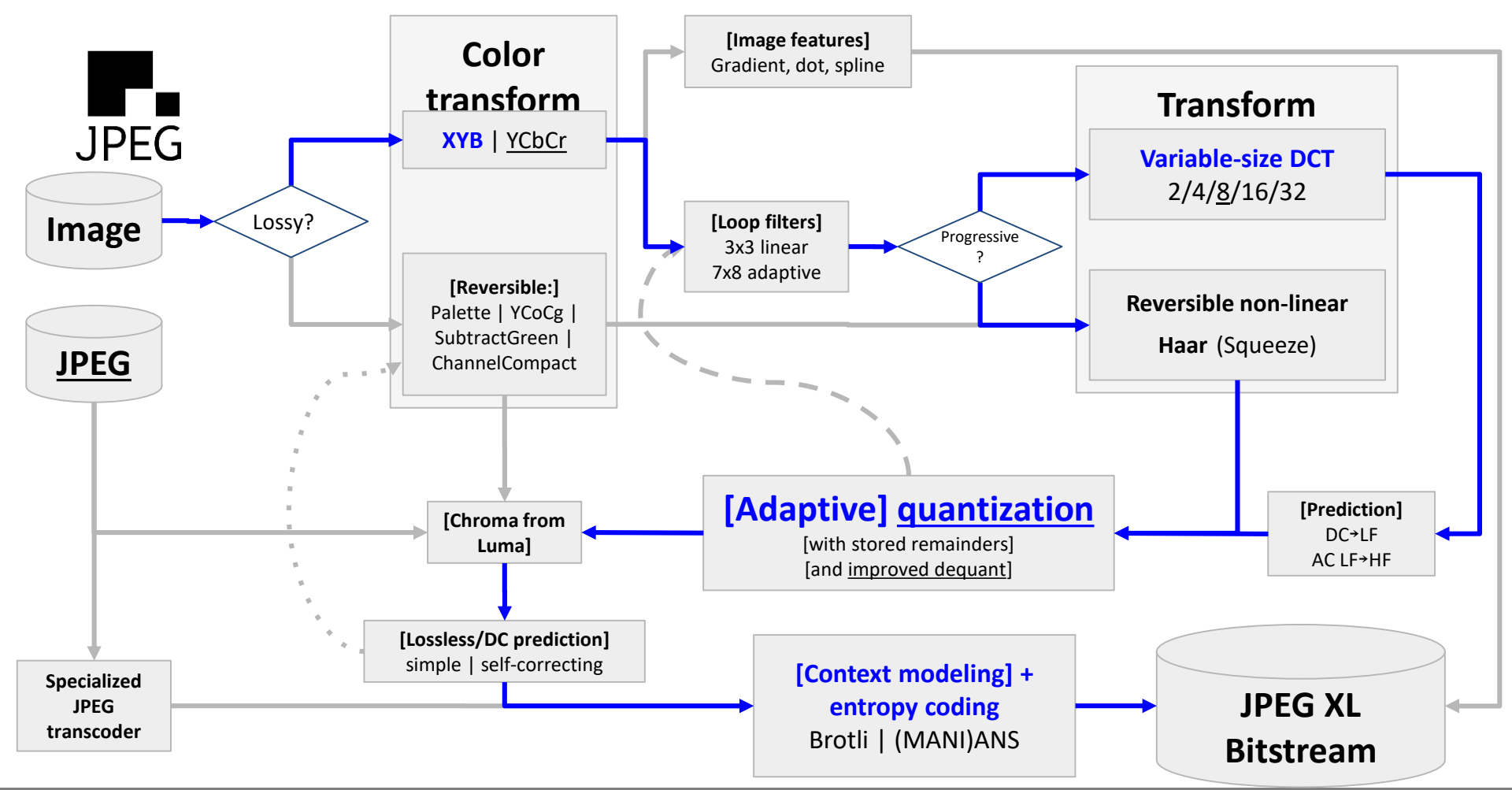
JPEG



sunset.jpg
6173 bytes

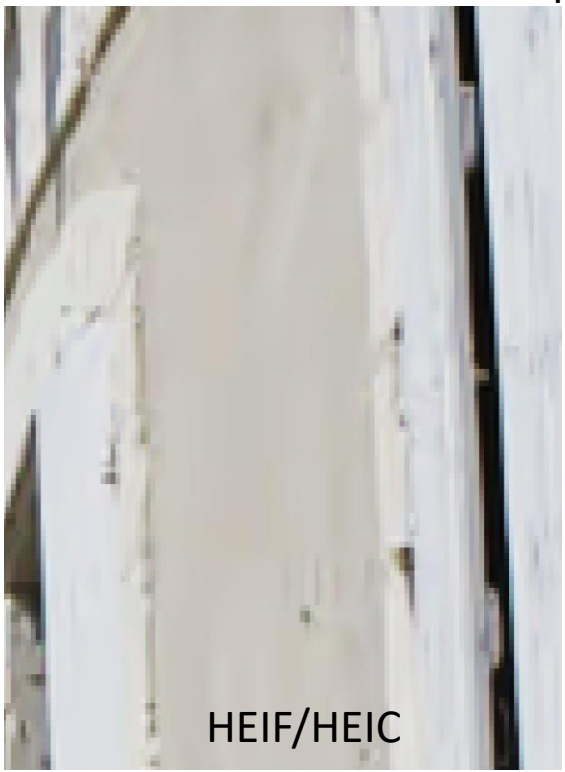
reversible

sunset.jxl
3320 bytes


JPEG
Image
JPEG
Lossy?
Color transform
XYB | YCbCr
[Reversible:]
Palette | YCoCg |
SubtractGreen |
ChannelCompact
[Image features]
Gradient, dot, spline
[Loop filters]
3x3 linear
7x8 adaptive
Progressive ?
Transform
Variable-size DCT
2/4/8/16/32
Reversible non-linear
Haar (Squeeze)
[Chroma from Luma]
[Adaptive] quantization
[with stored remainders]
[and improved dequant]
[Prediction]
DC→LF
AC LF→HF
[Lossless/DC prediction]
simple | self-correcting
Specialized JPEG transcoder
[Context modeling] + entropy coding
Brotli | (MANI)ANS
JPEG XL Bitstream

Compression efficiency

0.75 bpp



JPEG XL Workplan

Part	Title	WD	CD	DIS	FDIS	IS
1	JPEG XL: Image Coding System	19/03	19/07	19/11	-	20/04

More information

Prof. Touradj Ebrahimi
JPEG Convenor

École Polytechnique Fédérale
de Lausanne (EPFL)

Touradj.Ebrahimi@epfl.ch