JPEG White Paper:

JPEG XL image coding system

Version 1.1

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Executive summary

JPEG XL is a new image codec standardization project for capturing, storing, archiving, transmitting, and distributing photographic images as well as graphics, illustrations, mixed content (e.g. screenshots) and animations. JPEG XL fills the specific needs for responsive web, wide colour gamut, and high dynamic range applications. It provides legacy transition features, and effective compression at high visual quality. This document gives an overview of the JPEG XL architecture and features.

Introduction

The JPEG XL Image Coding System (ISO/IEC 18181) has a richer feature set than commonly used codecs. It is particularly optimised for responsive web environments, so that content renders well on a wide range of devices. Moreover, it includes several features that help transition from the legacy JPEG format. Existing JPEG files can be losslessly transcoded to JPEG XL, significantly reducing their size (Fig. 1). These can be restored into the exact same JPEG file, ensuring backward compatibility with existing JPEG-based applications. Both the transcoding and restoration are computationally efficient. Migrating to JPEG XL reduces storage costs because servers can store a single JPEG XL file to serve both JPEG and JPEG XL clients. JPEG XL encoders can also produce a backwards-compatible JPEG file, and can choose to add enhancement metadata. This file remains decodable by a legacy JPEG decoder, whereas a JPEG XL decoder uses the metadata (if present) to enhance image quality. These features are intended to provide a smooth transition from legacy JPEG platforms to the modern JPEG XL. Figure 1 illustrates these usage scenarios, indicating how JPEG XL can help to reduce server costs (storage size) and network bandwidth (transfer size).

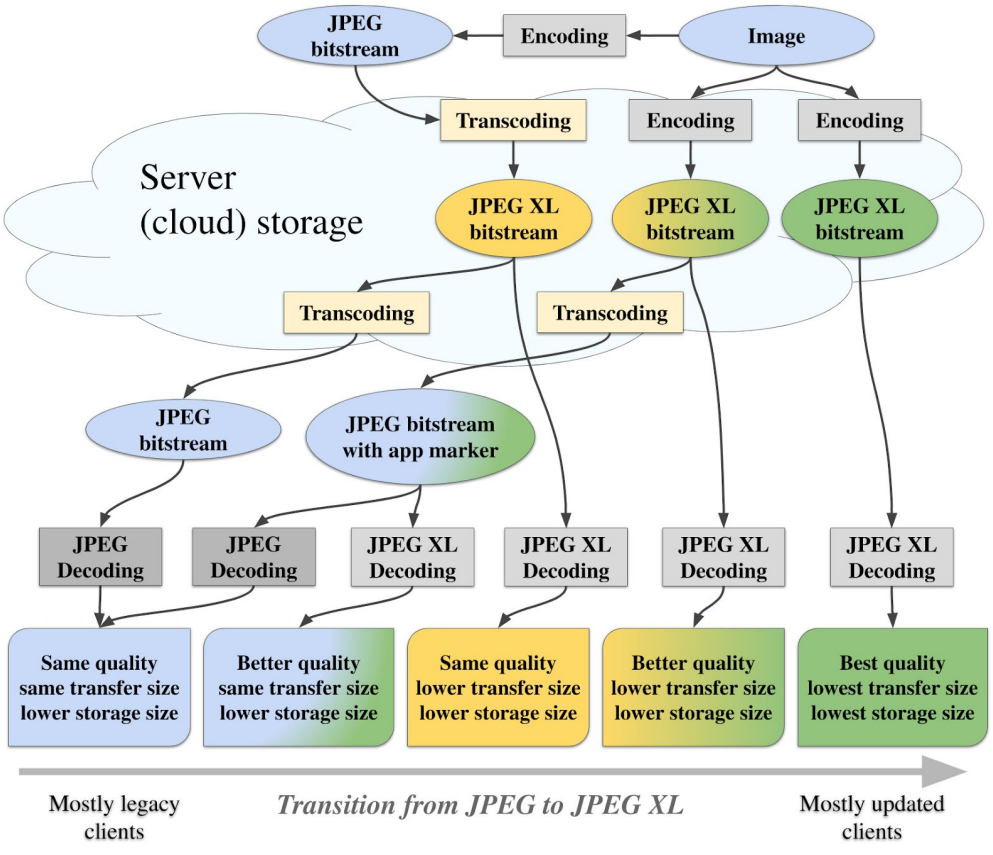

Fig. 1: Diagram illustrating usage scenarios

JPEG XL is designed to meet the needs of high-quality imaging and professional photography. It supports wide colour gamut as well as high dynamic range and high bit depth images. JPEG XL further includes features such as animation, alpha channels, layers, thumbnails, lossless and progressive coding to support a wide range of use cases[1] including but not limited to photo galleries, e-commerce, social media, user interfaces and cloud storage. To enable novel applications, it also adds support for 360 degree images, image bursts, large panoramas/mosaics, and printing.

JPEG XL offers significantly better image quality and compression ratios than legacy JPEG. Considering contemporary alternatives, JPEG XL has a short specification and allows a simple implementation. It is designed for computationally efficient encoding and decoding using software implementations without the need for additional hardware acceleration, even on mobile devices.

Key Features

An important goal for JPEG XL is a **royalty-free baseline**. The complete reference software is licensed under a **free and open source software** license (Apache 2.0), which includes a **patent grant** from the contributors.

The codec is designed to allow users to balance three primary criteria for their application:

- high fidelity to the source image,
- encoding and/or decoding speed,
- compression ratio (typically 20:1 to 50:1).

Key features of the JPEG XL codec are:

1. lossless JPEG transcoding,
2. encoder and decoder parallelization with border handling,
3. improved functionality and efficiency versus traditional image formats (e.g. GIF and PNG),
4. progressive decoding (resolution and precision),
5. designed to support both photographic and synthetic imagery,
6. smooth quality degradation across a range of bitrates,
7. region of interest decoding,
8. compressed ICC profile,
9. dithering using signalled synthetic noise,
10. suitable for automated operation.

In terms of compression performance, key results are:

- Lossless JPEG transcoding reduces JPEG size by typically **16 to 22%**.
- JPEG XL is visually lossless at about half the bitrate required by JPEG.
- In side-by-side comparisons, JPEG XL is visually lossless (shaded blue area) typically at similar bitrates as HEVC-HM-Y444. Figure 2 shows some results from an evaluation by EPFL[2].

[1] ISO/IEC JTC 1/SC 29/WG1, "JPEG XL Use Cases and Requirements" output document wg1n83043, Geneva, Switzerland (March 2019), https://jpeg.org/static/documents/wg1n83043-REQ-JPEG_XL_Use_Cases_and_Requirements.pdf. Accessed: 2020-01-10.
[2] J. Alakuijala et al., "Benchmarking JPEG XL image compression," Proc. SPIE 11353, Optics, Photonics and Digital Technologies for Imaging Applications VI, 113530X (1 April 2020); https://infoscience.epfl.ch/record/277420/files/Submitted%20manuscript.pdf. Accessed: 2020-05-07.

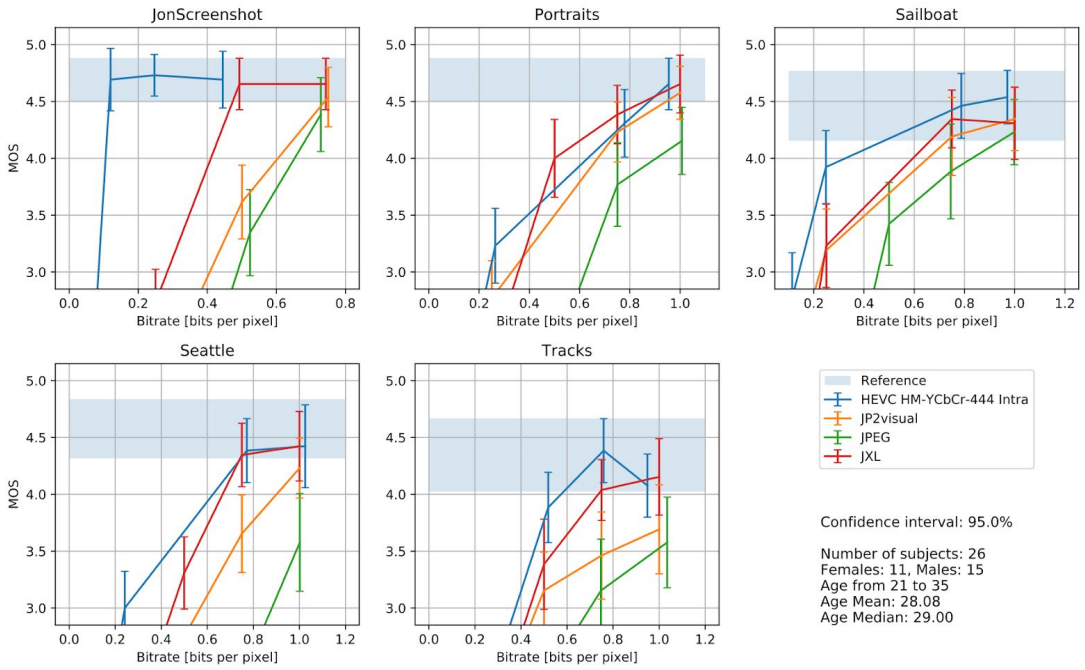

Fig. 2: Examples of subjective evaluations, with mean opinion scores for various bitrates.

Codec Architecture

JPEG XL has three modules, shown in the encoder diagram in Figure 3:

- Yellow: lossless transcoding of JPEG inputs
- Green: lossy encoding of photos with an emphasis on the human visual system
- Red: mathematically lossless encoding or generic lossy encoding

(Note that the red and green modules potentially also use the other module to store subimages)

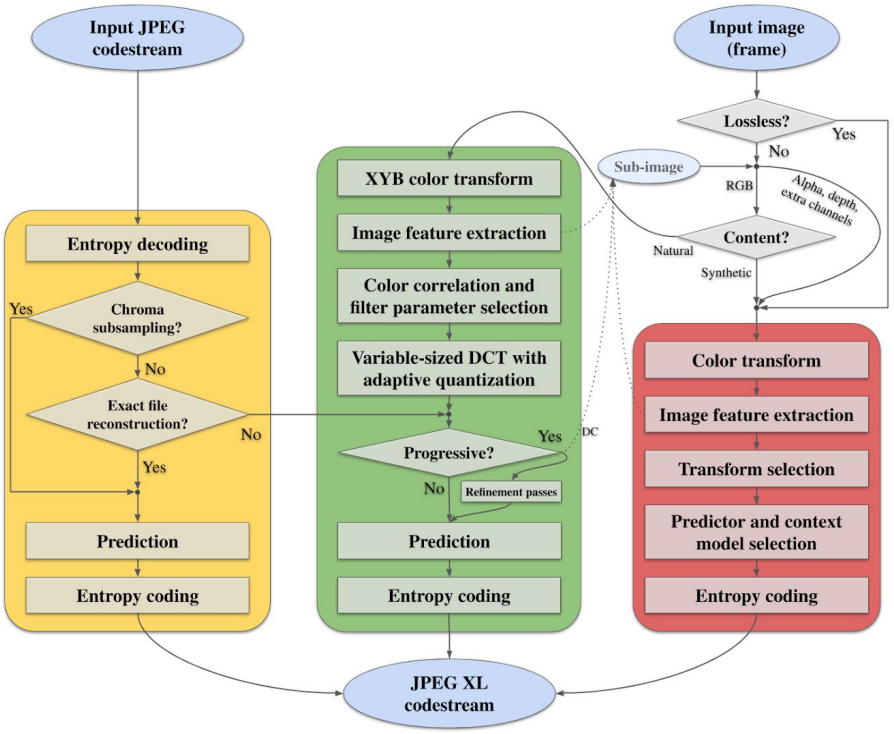

Fig. 3: Overview of the encoder architecture

Coding tools

JPEG XL can store one or more frames, e.g. for **animation** or overlays. Frames may be subtracted from prior frames without motion compensation and can have smaller bounding boxes, blend modes and dispose modes. They may also reference regions from prior frames marked as reference frames, which can serve as a simple **inter-frame** coding tool and as a **screen content** coding tool for still images.
Each frame is split into groups (256x256 pixels plus a border to ensure independence) for **parallel encoding/decoding** and efficient **region-of-interest** (cropped) decoding.

A brief description of the other JPEG XL coding tools follows.

- The XYB color transform is a hybrid color model inspired by the human visual system, facilitating perceptually uniform quantization. It uses a gamma of 3 for particularly efficient decoding.
- **Image features** are rendered on top of the decoded image, allowing more precise and economical representations of repeated or curvilinear image features, plus adaptive noise synthesis.
- **Color correlation** allows the decoder to predict chroma from luma using signaled local multipliers.
- Per-block **filter parameters** help to suppress artifacts while preserving fine detail.
- **Variable-sized DCT** (square or rectangular from 2x2 to 32x32) serves as a fast approximation of the optimal decorrelating transform. DCT coefficients may be sent in arbitrary order.
- **Adaptive quantization** uses per-block quantization step sizes which also guide the loop filter.
- **Prediction** is an adaptive, pixel-by-pixel decorrelator without side information.
- **Context modeling** includes specialized static models, local error based models, and meta-adaptive models with a signalled tree structure.
- **Entropy coding** uses Asymmetric Numeral System (ANS) or Huffman (for low-complexity encoders).
- **Transforms** include reversible color transforms (including a generalized palette transform) and a modified nonlinear Haar wavelet, which enables efficient and progressive decoding.
- **Progressive refinement** and responsive features include recursively progressive DC (cf. Figure 4), spectral selection and successive approximation passes for AC, saliency-based passes, and group permutation (e.g. center-to-border instead of scanline order, for example for 360 images).

Fig. 4: Example bitstream structure for progressive refinement

Conclusion

JPEG XL achieves efficient and high-quality image compression and responsive delivery. It is designed to be a practical and modern replacement for existing usages of JPEG, PNG and GIF formats. An advanced psychovisual model in the encoder enables visually lossless quality at compression ratios of around 20:1.

Open-source reference software is available at http://gitlab.com/wg1/jpeg-xl and additional information is available at https://jpeg.org/jpegxl/.