Jpeg-xl vs Avif vs Heic vs BCN vs Astc vs Webp vs Qoi vs Png vs Jpeg vs Jpeg2000 vs Exr vs Hdr vs Tiff

Multi Image Codec Introduction/Comparison

Larry Lin, Zhouyang He, Martin Yang

1. What's the problem? why is it important
    - Compression rate

      As digital storage continues to expand exponentially while being more cost-effective, the typical consumer might be less concerned about image file size. But increasing the compression rate still remains impactful for AI researchers, professionals in graphic, large-scale storage clusters, and the load of overall network traffic.

    - Decoding speed

      The speed of decoding may appear sufficient for the average user, but loading a single PNG might slow down the MCU in an embedded system. Even for modern PCs, the decoding rate can be unacceptable, as newer image codecs increase complexity by a factor of 10-100 or more. Also, most importantly, texture decoding has been a huge problem that requires GPU hardware and dedicated decoder.

- Compression Algorithm

  Many traditional algorithms did not consider the use of progressive or block encoding and were not designed with parallelism in mind. Concepts like resolution and different scales are not considered. Additionally, insufficient metadata design during standardization has caused significant problems for color management and future decoding.

- Field specific support

  Typical image codecs do not contain the information for field specific requirements（dynamic range, norm etc）, so that for 3d/vfx/photo/hdr, displaying, post processing, layer editing, and render passing is not possible.

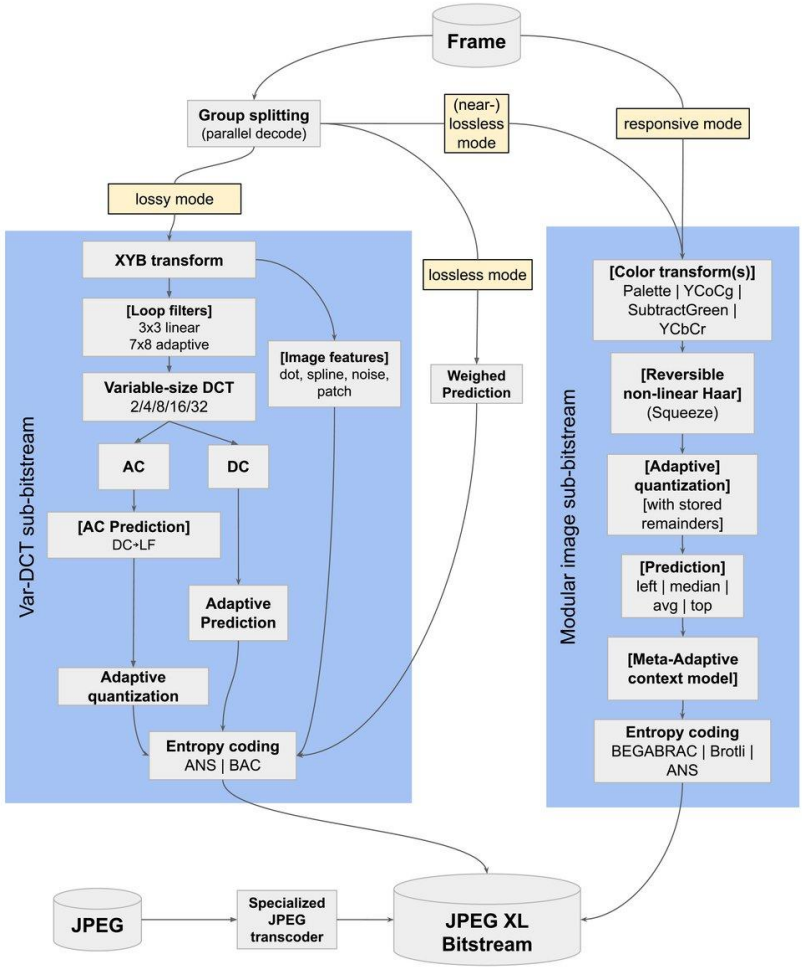
2. What has been done? Why are they not sufficient? including any of your previous, other and ongoing projects too
   - With the advent of newer formats such as AVIF and HEVC, the encoding rate has notably increased. However, the decoding time has also seen a 10x increase, and 20-50x for encoding time .
   - While jxl manages to reach the encoding rate of AVIF and HEVC and keep the de/encoding at faster speed, it still requires sufficient power to convince google.
   - Dedicated format has been standardized for different purpose such as exr/hdr for the field of vfx/3d, bc6/bc7/astc/etc for gpu achieving on the fly fast decompression, but field specific codec introduced problem like architectural limitation, unacceptable file size (single image over 2Gb)
   - Improving algorithms, adding Simd or native specific optimization can largely improve performance in different magnitudes. But simultaneously increase the complexity of porting the codec to alternative platforms and architectures, as well as implementing it at register transfer level.

——————————————————

Research result:

Jpeg-xl:

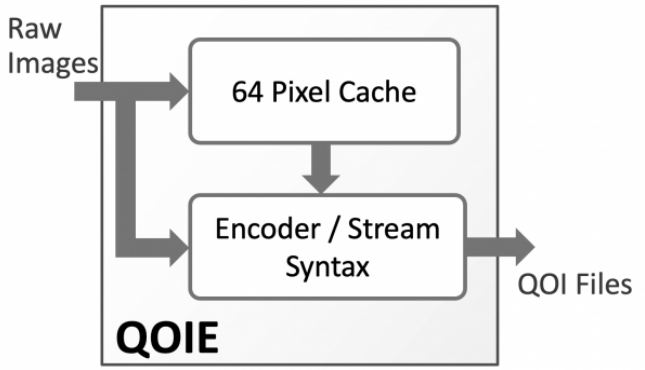
universal, fast enc/dec, support for lossy/lossless/frames/hdr
Encode steps:
Image to adaptive chunks for var-dct(8x8-64x64 into 4x4-8x4) (lossy)
encode in layers of quality for progressive rendering
Luma S LM difference color space transform(XYB)
Locally adjusted adaptive quantization
Block, lines, noise in compressed representation for reference
Entropy encoding with Asymmetric Numeral System + lz77(optional)
Weighted self correcting predictor adjusted per context with modeling (lossless)



Avif Heic:

Avif and Heic are part of the Av1/Hevc encoder where the frame based compression are used for storing individual image but achieving almost double the compression ratio of Png

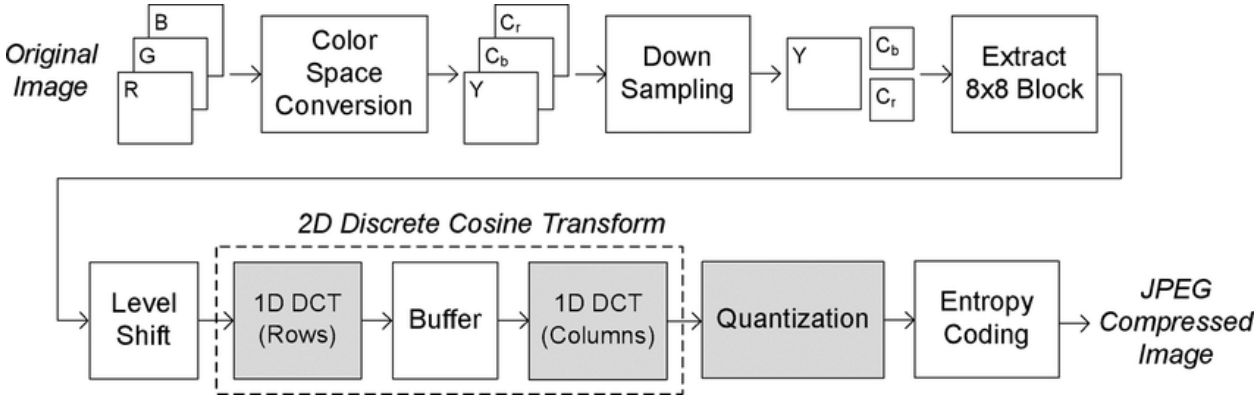
Qoi Png : dc rate, dc speed, usage, improvement, limitation



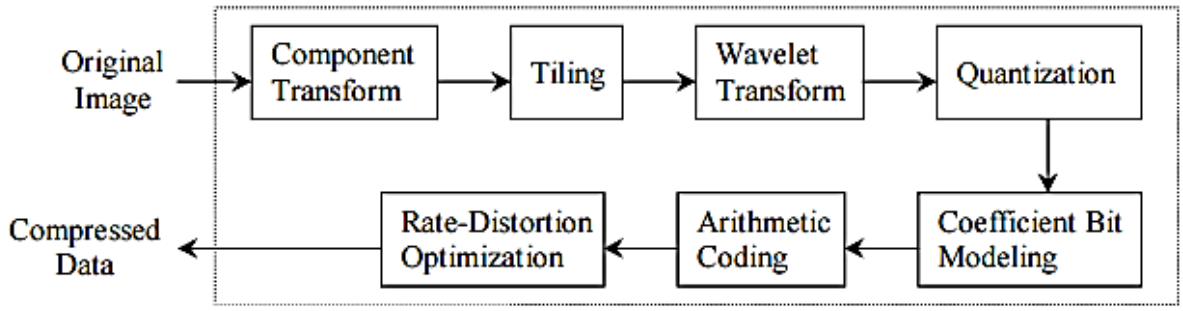
The QOI algorithm compresses RGB or RGBA images with 8 bits per color without any loss.

PNG uses DEFLATE, a non-patented lossless data compression algorithm involving a combination of LZ77 and Huffman coding

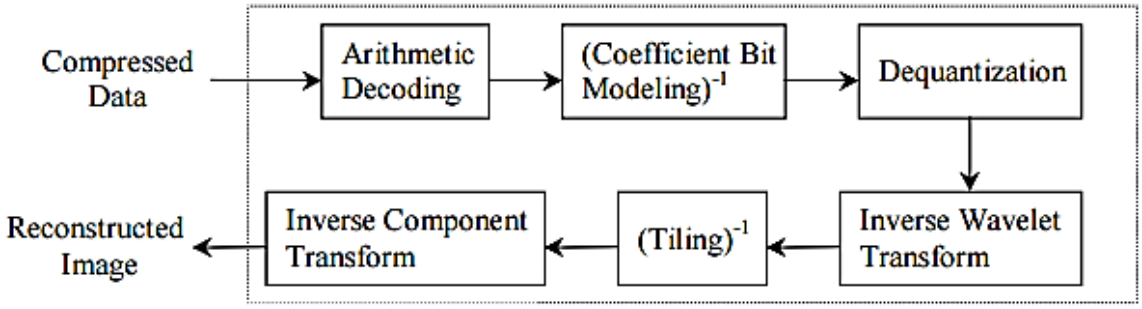
Jpeg Jpeg2000 Webp : usage, improvement, limitation



JPEG divides an image into blocks, transforms them into the frequency domain, quantizes high-frequency components, and applies entropy coding. This process compromises image quality but achieves significant compression.



Encoder Processing Steps



Decoder Processing Steps

JPEG 2000 uses wavelet transforms to efficiently encode and compress images. It offers superior image quality at lower bit rates compared to the original JPEG format and supports both lossless and lossy compression. JPEG 2000 is often used for medical imaging and archival purposes.

WebP is an image format specifically for web-based applications, employing techniques of both lossless and lossy compression. The WebP lossy compression employs the same VP8 methodology for frame prediction.The lossless WebP encoding involves a series of transformative operations applied to the image data.

BCn Astc:
Texture compression format features fast decompression for on the fly frame and block specific decompression in multi resolution for the purpose of rendering, the algorithm also considers implementation in hardware but architecture might be limited (astc on arm only)

Exr Hdr Tiff:
The OpenEXR(exr) is a high dynamic range image compression that is often used in film and vfx. It is designed to store and accurately represent images with a wide range of arbitrary image channels. These image channels can include RGBA, luminance and sub-sampled chroma channels; depth, surface normal directions, motion vectors ..etc

High Dynamic Range(hdr) image is a format used in film, photography and other industries, and hdr image files contain a wide range of luminance values allowing for a scene with varying levels of brightness and contrast. It uses floating point representation to store a wide range of values including very large and very small ones. Due to it is file size, compress algorithms are necessary to efficiently store and transmit images such as tone mapping algorithms.

Tagged Image File Format (TIFF) is widely utilized within the realms of design, photography, and desktop publishing industries. TIFF files are characterized by their capacity to retain detailed data, primarily employing lossless compression methods such as Lempel-Ziv-Welch compression. However, it is worth noting that due to their substantial file size, TIFF images are not considered optimal for implementation in web design or applications prefer short loading times. Alternatives like JPEG or PNG formats are typically favored in these contexts.

Uncovered graphical format:

Common or used in specific field:

gif, ico, xmb, dds, bmp, pnm, flif, rast, tga, s3tc, bc45, etc, pvrtc, eac, dxtc, svg, raws/container(psd/clip/ai/pdf/epsxcf/etc)

uncommon:

Bgp, fits, pcx, jpeg-xr, sgi, pik, ecw, jpeg-xt, …. +100 more

The Future of Image Format:

JPEG, PNG

—----------

3. What's your approach? Why can it do better or differently?
   Future Approach 1:
   Generative encoding:
   1000x compression ratio, represent 10MB image in 50-500B

   Approach 2:
   Lossy encoding:

Decent quality and good encoding ratio for all kind of texture(include extreme case)
Lossless encoding:
Compress the file more efficiently by applying multi-level encoding

4. Expected deliverables and a rough biweekly time schedule
   Oct. 21: Background research
   Nov. 4: Midterm update
   Nov.20: Demo and adjustment
   Dec: Final report and presentation

5. website url; any resources needed, references if any, etc
   https://shaoshanfan.wixsite.com/my-site-1

   References:
   https://jpegxl.info