The Best-Performance Digital Video Recorder

JPEG2000 DVR

V.S

M-PEG & MPEG4(H.264)

Many DVRs in the market
But it takes brains to make the best product

JPEG2000

The best picture quality in playback.
JPEG2000, the new still and moving image compression standard from the JPEG Committee, was designed to address the shortcoming of JPEG including:

- Better image quality
  - Up to 50% better Pixel SNR performance than JPEG
  - Compresses continuous tone and bi-level compression equally well
- Scalability - dynamic bandwidth / quality control possible
- Better error resilience compared to M-JPEG and MPEG4(H.246)
- Content-based description and image security (encryption, copyright info, etc)

JPEG2000 uses wavelet-based transform to achieve better compression

DCI (Digital Cinema Initiatives) selected JPEG2000 as a standard for digital cinema development

Member of DCI: Disney / Fox / MGM / Paramount / Sony Pictures / Entertainment / Universal / Warner Bros.
> Classification of Stand-Alone DVRs by Codec

1988
JPEG
H-263
M-JPEG

1994
MPEG-2
Wavelet

1998
MPEG-4
H.264

2000
JPEG2000

Sanyo, Mitsubishi, Neotech promote JPEG2000 Standalone DVR in the world market now.
> > Example: JPEG2000 and M-JPEG Picture (50:1)
JPEG2000 Image Comparison

ORIGINAL UNCOMPRESSED
IMAGE SIZE - 15466248 BYTES

The old JPEG can't compress this image any further. Look at the image to the right compressed 10 KB. that’s 1,500 to 1 compression ratio.

Why you need M-JPEG if you have JPEG2000!!
Example: JPEG2000 and MPEG4 Picture
JPEG2000 DVR vs. MPEG4 DVR to see the difference

JPEG2000 DVR

Quality: SUPER FINE

MPEG4 DVR

Quality: BEST

JPEG2000 DVR

Quality: BASIC

MPEG4 DVR

Quality: LOW
JPEG2000 DVR vs. MPEG4 DVR to see the difference

JPEG2000 DVR

Quality: SUPER FINE

MPEG4 DVR

Quality: HIGH
JPEG2000 DVR vs. MPEG4 DVR to see the difference

JPEG2000 DVR

Quality: BASIC

MPEG4 DVR

Quality: LOW
JPEG2000 DVR V.S M-PEG & MPEG4 (H.264)

> > JPEG 2000 Handles High Bit Error Rates*
  (Compression ratio of 80:1, BER of $10^{-4}$)

### Compression JPEG2000 vs. MPEG4(H.264)

<table>
<thead>
<tr>
<th>COMPARISON</th>
<th>JPEG2000</th>
<th>MPEG4(H.264)</th>
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<tbody>
<tr>
<td>Drives From</td>
<td>JPEG Still picture algorithm</td>
<td>MPEG Moving picture algorithm</td>
</tr>
<tr>
<td>Image Indexing</td>
<td>Easy</td>
<td>Difficult (some limitation in operation)</td>
</tr>
<tr>
<td>Advantage for DVR Use</td>
<td>No mosaic effect (blocks) in playback</td>
<td>Send more images via IP Network</td>
</tr>
<tr>
<td>Disadvantage for DVR Use</td>
<td>None. Best picture quality compared to any algorithm</td>
<td>Small resolutions Poor playback image</td>
</tr>
<tr>
<td>Best Application</td>
<td>Digital Movie Stand-alone DVR</td>
<td>Communications PC-Based DVR (network)</td>
</tr>
</tbody>
</table>

- **Stand-alone DVR systems** rely on focused recording and playback images with stability and reliability. Still picture algorithms allow for high resolution images and sequential image by image playback.

- **MPEG4 images** are only reliable when no movement occurs. Images are not stable when involved with many moving objects (ex. Images from PTZ cameras). Does not allow for high resolution, multiplexed, still pictures.
## Compression Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td><strong>Motion JPEG</strong></td>
<td>Most popular standard (cheapest to implement?); low process latency; used successfully in court</td>
<td>Least efficient compression compared to others; obvious degradation with any bit error; Unsuitable for text; no scalability</td>
</tr>
<tr>
<td><strong>MPEG2/4, H.264</strong></td>
<td>Ideal for streaming (very efficient compression, especially H.264); simpler decode process than encode; prevalent PC standard</td>
<td>Complicated encoding (MPEG4 /H.264); long process latency; weak error resilience (transmission errors affect multiple frames); License and user content fees for MPEG4; no still image capability (legal implications); not ideal for video editing; very limited scalability</td>
</tr>
<tr>
<td><strong>JPEG2000</strong></td>
<td>Low process latency (ADV202); better compression efficiency than JPEG; complete scalability; bit-error resilient; lossy / lossless capable; suitable for text and images;</td>
<td>Less compression efficient than MPEG (ex: DVD-quality- VERY rough estimate : 10 - 12 Mbps (JPEG2000); 8 - 10 Mbps (MPEG2); 4 - 6 Mbps (MPEG4))</td>
</tr>
</tbody>
</table>

**Say good bye to M-JPEG & MPEG4(H.264)
Standalone DVR, The right solution is JPEG2000**
Scalability of Video with JPEG2000*

Single stream of JPEG2000 video can be simultaneously distributed to display monitors of different resolution, frame rate, and quality; MPEG4 can do this with only a fixed format.

Diagram courtesy of NHK (Japan Public Broadcasting)
JPEG2000 in Surveillance
Simultaneously transmit different resolutions, frame rates, and quality levels with no transcoding.

- Highest quality image recorded for detailed review afterward.
- Medium quality image for monitoring at base.
- Low quality image for mobile monitoring (for lower transmission bandwidth via wireless).
Why consider JPEG2000 when there is MPEG2/4 or H.264?

- More flexibility - encode at the highest quality (for detailed viewing) but only send portions that fit lower transmission bandwidth, resolution, frame rate, etc.

  - To address HDD space concerns, the customer can reduce bit rate during scenes with no motion and increase quality when motion is detected

- Low latency - useful in remotely operating a camera
- Multiplexing multiple cameras - not possible with MPEG4(H.264)
- Regions of motion can be enhanced - not possible with MPEG4(H.264)
- Higher image quality - MPEG4(H.264) is not conducive toward this trend since it is 8-bits only and has no still image capability
- Legal Issues – Some countries (Australia) do not allow MPEG4(H.264) still images as legal evidence (JPEG, on the other hand, has been used in the UK courts)
- MPEG4(H.264) is “digital VHS” – nothing can be done with the data
Appendix

ISO/IEC JTC1/SC29/WG1 N1816 July 2000

ISO/IEC JTC1/SC29/WG1 (ITU-T SG8)

Coding of Still Pictures JBIG JPEG

Joint Bi-level Image Joint Photographic Experts Group Experts Group

TITLE: An analytical study of JPEG 2000 functionalities

ABSTRACT
JPEG 2000, the new ISO/ITU-T standard for still image coding, is about to be finished. Other new standards have been recently introduced, namely JPEG-LS and MPEG-4 VTC(H.264). This paper compares the set of features offered by JPEG 2000, and how well they are fulfilled, versus JPEG and MPEG-4 VTC(H.264). The study concentrates on compression efficiency and functionality set, while addressing other aspects such as complexity. Lossless compression efficiency as well as the fixed and progressive lossy rate-distortion behaviors are evaluated. Robustness to transmission errors, Region of Interest coding and complexity are also discussed. The principles behind each algorithm are briefly described. The results show that the choice of the “best” standard depends strongly on the application at hand, but that JPEG 2000 supports the widest set of features among the evaluated standards, while providing superior rate-distortion performance in most cases.

INTRODUCTION
It has been three years since the call for proposals 1 for the next ISO/ITU-T standard for compression of still images, JPEG 2000, has been issued. Now JPEG 2000 Part I (the core system) is in its final stage to become an International Standard (IS). It has been promoted to Final Committee Draft (FCD) 2 in March 2000 and will reach IS status by the end of the same year. A great effort has been made to deliver a new standard for today's and tomorrow's applications, by providing features inexistent in previous standards, but also by providing higher efficiency for features that exist in others. Now that the new standard is nearing finalization, a trivial question would be: what are the features offered by JPEG 2000 but also how well are they fulfilled when compared to other standards offering the same features. This paper aims at providing an answer to this simple but somewhat complex question. Section 2 provides a brief overview of the techniques compared, with special attention on new features of JPEG 2000 such as Region of Interest (ROI) coding. Section 3 explains the comparison methodology employed in the results shown in section 4 and conclusions are drawn in section 5.
OVERVIEW OF STILL IMAGE CODING STANDARDS

For the purpose of this study we compare the coding algorithm in JPEG 2000 standard to the following three standards: JPEG, MPEG-4 Visual Texture Coding (VTC). The reasons behind this choice are as follows. JPEG is one of the most popular coding techniques in imaging applications ranging from Internet to digital photography. MPEG-4 VTC is very recent standards that start appearing in various applications. It is only logical to compare the set of features offered by JPEG 2000 standard not only to those offered in a popular but older standard (JPEG), but also to those offered in most recent ones using newer state-of-the-art technologies.

**JPEG**

This is the very well known ISO/ITU-T standard created in the late 1980s. There are several modes defined for JPEG, including baseline, lossless, progressive and hierarchical. The baseline mode is the most popular one and supports lossy coding only. The lossless mode is not popular but provides for lossless coding, although it does not support lossy.

In the baseline mode, the image is divided in 8x8 blocks and each of these is transformed with the DCT. The transformed blocks are quantized with a uniform scalar quantizer, zig-zag scanned and entropy coded with Huffman coding. The quantization step size for each of the 64 DCT coefficients is specified in a quantization table, which remains the same for all blocks. The DC coefficients of all blocks are coded separately, using a predictive scheme. Hereafter we refer to this mode simply as JPEG.

The lossless mode is based on a completely different algorithm, which uses a predictive scheme. The prediction is based on the nearest three causal neighbors and seven different predictors are defined (the same one is used for all samples). The prediction error is entropy coded with Huffman coding. Hereafter we refer to this mode as L-JPEG.

The progressive and hierarchical modes of JPEG are both lossy and differ only in the way the DCT coefficients are coded or computed, respectively, when compared to the baseline mode. They allow a reconstruction of a lower quality or lower resolution version of the image, respectively, by partial decoding of the compressed bitstream. Progressive mode encodes the quantized coefficients by a mixture of spectral selection and successive approximation, while hierarchical mode uses a pyramidal approach to computing the DCT coefficients in a multi-resolution way.

**MPEG-4 VTC (H.264)**

MPEG-4 Visual Texture Coding (VTC) is the algorithm used in MPEG-4 to compress visual textures and still images, which are then used in photo realistic 3D models, animated meshes, etc., or as simple still images. It is based on the discrete wavelet transform (DWT), scalar quantization, zero-tree coding and arithmetic coding. The DWT is dyadic and uses a Daubechies (9,3) tap biorthogonal filter. The quantization is scalar and can be of three types: single (SQ), multiple (MQ) and bi-level (BQ). With SQ each wavelet coefficient is quantized once, the produced bitstream not being SNR scalable. With MQ a coarse quantizer is used and this information coded. A finer quantizer is then applied to the resulting quantization error and the new information coded. This process can be repeated several times, resulting in limited SNR scalability. BQ is essentially like SQ, but the information is sent by bitplanes, providing general SNR scalability. Two scanning modes are available: tree-depth (TD), the standard zero-tree scanning, and band-by-band (BB). Only the latter provides for resolution scalability. The produced bitstream is resolution scalable at first, if BB scanning is used, and then SNR scalable within each resolution level, if MQ or BQ is used.

A unique feature of MPEG-4 VTC is the capability to code arbitrarily shaped objects. This is accomplished by the means of a
shape adaptive DWT and MPEG-4’s shape coding. Several objects can be encoded separately, possibly at different qualities, and then composited at the decoder to obtain the final decoded image. On the other hand, MPEG-4 VTC does not support lossless coding.

**JPEG 2000**

JPEG 2000\(^2\), as noted previously, is the next ISO/ITU-T standard for still image coding. In the following, we restrict the description to Part I of the standard, which defines the core system. Part II will provide various extensions for specific applications, but is still in preparation. JPEG 2000 is based on the discrete wavelet transform (DWT), scalar quantization, context modeling, arithmetic coding and post-compression rate allocation. The DWT is dyadic and can be performed with either the reversible Le Gall (5,3) taps filter\(^9\), which provides for lossless coding, or the non-reversible Daubechies (9,7) taps biorthogonal one\(^10\), which provides for higher compression but does not do lossless. The quantizer follows an embedded dead-zone scalar approach and is independent for each sub-band. Each sub-band is divided into rectangular blocks (called code-blocks in JPEG 2000), typically 64x64, and entropy coded using context modeling and bit-plane arithmetic coding. The coded data is organized in so called layers, which are quality levels, using the post-compression rate allocation and output to the code-stream in packets. The generated code-stream is parseable and can be resolution, layer (i.e. SNR), position or component progressive, or any combination thereof. JPEG 2000 also supports a number of functionalities, many of which are inherent from the algorithm itself. Examples of this is random access, which is possible because of the independent coding of the code-blocks and the packetized structure of the codestream. Another such functionality is the possibility to encode images with arbitrarily shaped Regions of Interest (ROI)\(^11\). The fact that the subbands are encoded bitplane by bitplane makes it possible to select regions of the image that will precede the rest of the image in the codestream. By scaling the sub-band samples so that the bitplanes encoded first only contain ROI information and following bitplanes only contain background information. The only thing the decoder needs to receive is the factor by which the samples were scaled. The decoder can then invert the scaling based only on the amplitude of the samples. Other supported functionalities are error-resilience, random access, multicomponent images, palletized color, compressed domain lossless flipping and simple rotation, to mention a few.

**Table.** Functionality matrix. A “+” indicates that it is supported, the more “+” the more efficiently or better it is supported. A “-” indicates that it is not supported.

<table>
<thead>
<tr>
<th></th>
<th>JPEG 2000</th>
<th>JPEG</th>
<th>MPEG-4 VTC(H.264)</th>
</tr>
</thead>
<tbody>
<tr>
<td>lossless compression performance</td>
<td>+++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>lossy compression performance</td>
<td>+++++</td>
<td>+++</td>
<td>++++</td>
</tr>
<tr>
<td>progressive bitstreams</td>
<td>+++++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Region of Interest (ROI) coding</td>
<td>+++</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>arbitrary shaped objects</td>
<td>-</td>
<td>-</td>
<td>++</td>
</tr>
<tr>
<td>random access</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>low complexity</td>
<td>++</td>
<td>+++++</td>
<td>+</td>
</tr>
<tr>
<td>error resilience</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>non-iterative rate control</td>
<td>+++</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>genericity</td>
<td>+++</td>
<td>++</td>
<td>++</td>
</tr>
</tbody>
</table>
MPEG-4 VTC, as JPEG 2000, is able to produce progressive bitstreams without any noticeable overhead. However, the latter provides more progressive options and produces bitstreams that are parseable and that can be rather easily reorganized by a transcoder on the fly. Along the same lines, JPEG 2000 also provides random access (i.e. involving a minimal decoding) to the block level in each sub-band, thus making possible to decode a region of the image without having to decode it as a whole. These two features could be very advantageous in applications such as digital libraries.

Another result of the fact that JPEG2000 generates progressive bitstream is the Region of Interest functionality. As shown in the previous section it is possible to generate a bitstream in which specific areas of the image are refined earlier than the rest. The bitstream can be organized so that either the image is stored with the same quality for the ROI and the rest of the image, or if the bitstream is truncated, the ROI will have better quality than the background.

Concerning error resilience JPEG 2000 offers higher protection than JPEG, as shown in the previous section. MPEG-4 VTC also offers error resilience features and although it could not be evaluated, the support is expected to be in between JPEG and JPEG 2000.

Overall, one can say that JPEG 2000 offers the richest set of features and provides superior rate-distortion performance. However, this comes at the price of additional complexity when compared to JPEG, which might be currently perceived as a disadvantage for some applications, as was the case for JPEG when it was first introduced.

CONCLUSIONS

This work aims at providing a comparison of the efficiency of various features that can be expected from a number of recent as well as most popular still image coding algorithms. To do so, many aspects have been considered including genericity of the algorithm to code different types of data in lossless and lossy way, and features such as error resiliency, complexity, scalability, region of interest, embedded bitstream and so on.

The results presented in previous sections show that from a functionality point of view JPEG 2000 is a true improvement, providing lossy and lossless compression, progressive and parseable bitstreams, error resilience, region of interest, random access and other features in one integrated algorithm. However, while new standards provide higher compression efficiency there is no truly substantial improvement. This is especially true for lossy coding, even though the new standards are significantly more complex than JPEG.

In any case, the choice of a standard for a particular application or product will depend on its requirements. As for MPEG-4 VTC, it appears to be of limited interest, except when the ability to code arbitrarily shaped objects is required. JPEG 2000 provides the most flexible solution, combining good compression performance with a rich set of features.