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JPEG2000 - THE NEW CONTENDER IN CONTENT PRODUCTION AND TRANSPORT

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ABSTRACT

The evolution of compression in broadcasting has not stopped at MPEG-4, but has shifted into a higher gear with the adoption of a compression scheme originally developed for digital cinema. It is a more efficient compression than the original discrete cosine transform used in the MPEG family, producing softer artifacts that are less annoying to the viewer. It's a very flexible and scalable compression that permits the extract of multiple resolution images from a single high-resolution master.

JPEG 2000 is based on wavelet technology that transforms images into wavelet coefficients sub-bands and resolutions supporting both lossless and lossy compression. Lossless compression is typically reported within a range to 3:1 ratio, which would be excellent for the production and transport of high definition content in both 1080-Interlace and Progressive image formats. Moreover, wavelet transform operates over the entire image at multiple resolutions, therefore, bit error artifacts are manifested into blurred images rather than blocking.

In addition to some technological advantages, JPEG2000 does not carry licensing costs, making its use more advantageous in economic terms for the broadcast industry. Some manufacturers have already started with an early implementation of this compression technology by addressing specific segments of the broadcast chain, namely acquisition and transport.

This compression scheme may yield additional advantages for the broadcasting industry in the production of high definition content and transport, as you will soon observe hereunder .

INTRODUCTION

JPEG2000 is the first international standard for image compression developed jointly by the International Organization for Standardization (ISO), and International Electrotechnical Commission (IEC), and also recommended by the International Telecommunications Union (ITU). The activity toward definition of the image compression standard originally started as early as 1982 and finally the JPEG (Joint Photographic Experts Group) was formed in 1987. However, JPEG for still image compression became an international standard in 1992. The JPEG standard describes a family of image compression techniques rather than a single compression technique. It provides a toolkit of compression techniques from which an application can choose the elements needed to meet its requirements. The standard has four different modes of operation, each mode consisting of a multiple number of options as well as totaling 44 different options or sub-modes. A particular option is a restricted form of the sequential Discrete Cosine Transform (DCT)- based mode in JPEG called *baseline JPEG.*

Since the definition of the JPEG standard, the technology world and the marketplace have gone through a significant transformation because of the advent of Internet technology, its massive deployment and usage in every walk of life, and significant progress in multimedia and communications technologies and their applications. Although JPEG has been very successful in the marketplace for more than a decade, it lacks many features desired by interactive multimedia applications, its usage in current communications (wired and wireless) environments, and Internet applications platforms.

A fundamental shift in the image compression approach came after the Discrete Wavelet Transform (DWT) became popular. To overcome the inefficiencies in the JPEG standard and serve emerging applications areas in the age of mobile and Internet communications, the new JPEG2000 standard has been developed based on the principles of DWT. Currently, more developments in this standard are in progress in the ISO/IEC standard committee.

JPEG 2000 incorporated the latest advances in image compression to provide a unified optimized tool to accomplish both lossless and lossy compression and decompression, using the same algorithm and the bitstream syntax. JPEG2000 standard will be effective in wide application areas such as Internet, digital photography, digital video, and mobile multimedia,. However, its main drawback compared with the current JPEG is that the coding algorithm is much more complex and the computational needs are much higher.

THE NEW COMPRESSION PHILOSOPHY

The underlying philosophy behind the development of the JPEG2000 standard was to compress an image once and decode the compressed bitstream in many ways to meet different application requirements. Some of the salient features offered by the JPEG 2000 standard that may be effective in broadcasting applications are as follows:

- Lossless and lossy compression: The single unified compression architecture can provide both the lossless and the lossy mode of image compression. Thus, lossy and lossless decompression are also possible from a single compressed bitstream.

- Progressive accuracy and resolution: It is possible to organize the code-stream in a progressive manner in terms of video quality, allowing the construction of images with increasing pixel accuracy as more and more compressed bits are received and decoded. This is possible by progressively decoding most significant bit-planes to lower significant bit-planes until all the bit planes are reconstructed. The process is by decoding and inverse DWT of increasingly subbands that were generated by the multi-resolution decomposition of the image by DWT. These features are very effective for real-time browsing of images on the Web, downloading the images in a system with limited memory buffer, transport of video through limited-bandwidth channels, and decoding the video depending on the available resolution of the rendering system.

- Random access and compressed domain processing: It is possible to manipulate certain areas of the image by extracting the codeblocks from the compressed stream. Some examples of compressed-domain processing are cropping, scaling, feature extraction, flipping, and rotations. This process permits the replacement of one object in the image with another, sometimes even with a synthetically generated image object. This feature might be useful in video editing, animation, graphics, etc.

- Image security: It is possible to introduce image security features into a JPEG 2000-compliant compressed file by inserting watermarks, fingerprints, or intellectual property rights information, etc. The JPEG2000 standards committee's definition of Part 8 of the standard is not yet finalized. Once it is, Part 8 of the standard will guide the issues of image security and their implementation in a JPEG2000-compliant system.

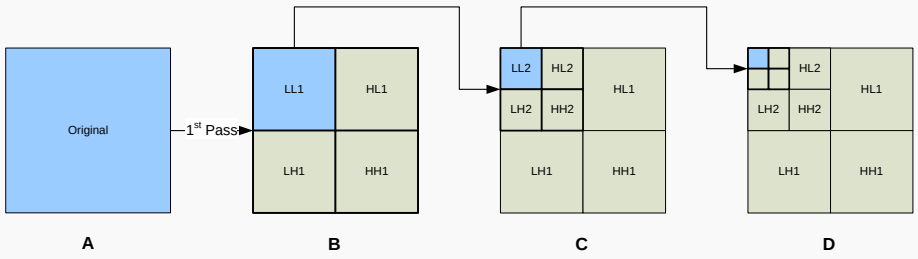
- There are other applications of the JPEG2000 standard, such as mobile multimedia communications, 3G cellular telephony, and satellite imagery, that will not be discussed in this article.

An important feature of JPEG 2000 compression is the ability to extract a variety of resolutions, components, areas of interest and compression ratios from a single JPEG 2000 codestream. This is not possible with any other compression standard because the image size, bit rate and quality must be specified on the encode side and cannot be determined or changed on the decode side.

JPEG 2000 TRANSPORT STREAM

JPEG2000 defines syntax and rules to organize the compressed bitstream so that it can be uniquely decoded by any system compliant to the standard. The JPEG 2000 Part 1 standard defines a file format called JP2, which is a wrapper containing the compressed codestream. The fundamental building block of the JP2 file format is called a "box", and is used to encapsulate the JPEG 2000 codestream and other pieces of information, such as image properties, intellectual property rights, vendor specific information, and so forth.

A codestream is created by sending a given input image to a set of wavelet filters that transform the pixel information into wavelet coefficients. Those coefficients are then grouped into several subbands, with each one containing wavelet coefficients that describe a specific horizontal and vertical spatial frequency range of the entire original image. This means that lower-frequency, less-detailed information is contained in the first transform level, with more detailed, higher-frequency information contained in the higher transform levels. As an example and for the sake of simplicity, only two levels of transform will be used. The first transform level results in subbands LH1, HH1, HL1, and LL1. Only subband LL1 is passed on for further filtering, generating the next transform level and creating subbands LH2, HH2, HL2, and LL2 transform.



Bitstreams of data in the form of equally sized codeblocks are generated within each subband and are necessary for coefficient modeling and coding performed on a codeblock-by-codeblock basis. Thus, the compression is achieved by re-quantizing the bitstreams contained in each block, and the codeblocks can then be accessed independently. This process is used to assign information about the importance of each individual coefficient. Consequently, codeblocks can be grouped according to their significance. On the decoding side, it is then possible to extract information according to its significance, allowing the most significant information can be seen first.

JPEG 2000 can contain up to 16 layers of entropy coding known as rate-distortion optimization (RDO). Each layer contains a particular compression rate that is derived from the quantization, rate distortion and context modeling processes. As an example, Layer 0 contains bitstreams that were not truncated, providing the lowest compression rate and the highest quality. However, Layer 16 contains bitstreams from the lossy DWT, which is re-quantized and ordered according to codeblock significance, providing the highest compression rate and the lowest quality.

The JPEG 2000 stream starts with a main header that contains information about the image, such as size, number of components, bit depth of components, coding style, transform levels, progression order, number of layers, codeblock size, wavelet filter type and quantization level. This "table of contents" can be stored on the encode side and allows the decoder to select certain resolutions on demand without the need to decode the entire stream. The entire image data, grouped in codeblocks of LL, HL, LH, and HH subbands, always follows the header.

HDTV APPLICATIONS

The computer industry has evolved to a level where video can be recorded and transported using IT tools. This migration is well underway in production and playout systems, and moving into acquisition as well. Many applications, like HD, require exact bit rate control and JPEG 2000 becomes the potential enabler; exact bit rate control is feasible because an entire frame or field is transformed at once. It's then broken down into bitstreams or codeblocks that can be processed independently. This is in contrast to the alternative of breaking the frame or field into 8x8 pixel blocks prior to transform with DCT, making exact bit rate control impractical.

The bit rate control algorithm used in JPEG 2000 truncates each bitstream to meet a specific target bit rate, adjusting the truncation and re-quantization of each code block's required data. Moreover, the standard allows the user to specify a particular quality metric. As a result, the target bit rate will vary to meet the specified quality factor, providing the performance does not fall below a specific peak signal-to-noise ratio (PSNR), which is an indication of the picture quality.

This compression applies intraframe coding without exploiting temporal redundancy. However, for the purpose of content production, I-Frame compression is the preferred option. While there is a lack of comprehensive, comparative tests between JPEG 2000 and MPEG-2 or MPEG-4 AVC, it is expected that these types of comparative tests will be performed by the various broadcast organizations as hardware becomes available in the marketplace.

At the time of this writing, it's expected that at NAB2006, more manufacturers will be offering demos and new hardware featuring the advantages of JPEG 2000 compression for HD. This wavelet compression combined with the development of the 424M Draft SMPTE Standard for Television, encompassing 3 Gbps Signal/Data Serial Interface, may provide the tools for producing television content in a progressive format at the highest resolution.

INTERNET APPLICATIONS

As mentioned earlier in this article, "progressive accuracy and resolution" is a feature of JPEG 2000 that permits the bitstream to be coded in such a way as to contain less detailed information at the beginning of the stream and more detailed information as the stream progresses. This feature is ideal for Internet applications where large images can become accessible on low bandwidth; lower subbands are shown first, and more detail is added as time progresses. This

means that the picture becomes sharper and more detailed over time, and the entire image does not need to be downloaded before it can be viewed.

Therefore, with the low-quality image instantly available, the user at the receiving end can decide whether to view the picture in its fully decoded version, or to pass it by and scan the next image.

In addition, JPEG 2000 coding provides the option to zoom in on a particular area of the image or to display a particular region of the image at different resolutions.

CONCLUSION

JPEG2000 is frame-accurate for post-production editing, and a single high-resolution master image file can be used to simultaneously create lower-resolution files during the decoding process. Some manufacturers of broadcast HD products recently announced their intention to implement JPEG 2000 compression in their HD products, such as HD cameras, tapeless VTRs, and servers.

An inherit advantage of the compression scheme is the possibility of extracting multiple resolutions from a single compressed stream without transcoding, avoiding the potential creation of transcoding artifacts.

JPEG 2000 is a royalty-free technology that solves many of current compression dilemmas and is being adopted by the broadcast industry (i.e., server manufacturers, cameras, disk recorders, transport coding, etc.). The fact that JPEG 2000 carries no license cost makes this technology attractive.

Broadcasters can look for even more JPEG 2000-based equipment to become available in the future. Its combination of I-Frame for accurate editing, low latency, multiple-resolutions decoding capabilities, and no royalties make this technology attractive for professional broadcasting applications.

There is still a lot of work ahead for assessing the performance of products featuring JPEG2000 in contrast to the well established MPEG-2 and MPEG-4 compression schemes. JPEG 2000 standards are still in development and it may take some time to optimize the implementation of this new compression scheme into broadcast hardware.

CBC Technology is monitoring the progress of JPEG2000 implementation on production hardware and software, and will eventually commence the assessment of products featuring this new compression scheme for the production and transport of HD programming, including news.

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