Unified Still and Video Archiving and Distribution with JPEG 2000 & Arch-BEAM

Andrew Leung and Eisaburo Itakura
Sony Corporation
Tokyo, Japan

Abstract

This paper discusses JPEG 2000 as a unified compression standard for archiving and distribution of still images, video, and real-time video.

JPEG 2000 has many features for archiving and distribution such as: "encode once; decode many" flexibility, optimized network transfer, and extensibility to other imaging applications such as document imaging, intra-frame video, low-delay real-time video, and more.

We will discuss a case study in document imaging and low-delay real-time video forming a basis for a unified archiving and distribution system. A case study is presented for a Japanese newspaper company utilizing JPEG 2000 in their internal workflow to archive, distribute, and work more effectively.

The next step is to utilize JPEG 2000 as the format to archive and distribute video. In this paper, Arch-BEAM, is introduced in detail. Arch-BEAM system is a complete: capture, encode, storage, and delivery system for real-time or on-demand streaming video. Arch-BEAM also has real-time quality of service technology for efficient bandwidth utilization, real-time error control and recovery. From Arch-BEAM, a new concept of real-time archiving and scalable distribution for video is introduced. The Arch-BEAM system allows one to monitor the capture in real time and at the same time to archive the master and distribute various lower resolutions for various clients over various networks.

With more organizations adopting JPEG 2000 as a standard format of their own, interchange between organizations will be easier and support between them will multiply with enhanced resources. To simplify workflows and technical support, using JPEG 2000 is the best choice for not only from an archive point of view but for distribution as well. Adoption of JPEG 2000 in archiving will bring digital archiving and distribution to a new level.

Keywords: JPEG 2000; image; video; archive; distribution; Arch-BEAM; real-time; scalable delivery

Introduction

JPEG 2000 is the next generation image compression standard from the Joint Photographic Experts Group, JPEG. The current JPEG standard originated from this group and has revolutionized personal digital imaging. JPEG 2000 is an open international standard and is referenced as: ISO/IEC 15444-1.[1]

Digital archiving and distribution with JPEG 2000 is greatly enhanced from many features in JPEG 2000 such as:

Open International Standard

As an open international standard, anyone may implement JPEG 2000 as well. No single individual or vendor controls the standard. Anyone may implement their own version of JPEG 2000 and following appropriate standards will guarantee interoperability between other systems using JPEG 2000.

Scalability

JPEG 2000's wavelet transform and EBCOT coding allow the codestream to be decompressed in many ways after you encode: "encode once; decode many." If a thumbnail of the image is desired, only 5% of the compressed data will give you the right amount of data. JPEG 2000 is designed so that truncating the file at any moment will leave a recognizable image.

Network Transfer

JPEG 2000's codestream is specifically constructed to emulate network packets. When streaming JPEG 2000 image on the network, packetization of the JPEG 2000 codestream is simple. An RTP format specifically designed for JPEG 2000 enhances scalability and extends flexibility of the codestream. With the inherent layered features of JPEG 2000, it is easy to provide and extract desired data.

Visually Lossless

With an accurate and flexible rate control, implementers may vary the rate control scheme of the encoder and still produce valid JPEG 2000 files. One area of research is to find a rate control scheme which produce "visually lossless" compressed files. The files are still compressed in a lossy manner, which all the data going into the encoder does not come out of the decoder, but visually, there is no difference between the original under normal viewing conditions. [2]

Flexibility

JPEG 2000's flexibility is not only in the compressed codestream itself but within the standard. There is a whole family of standards extending JPEG 2000's still image

coding from internal codestream extensions, to intra-frame video, to document imaging, to network streaming, to even 3D volumetric coding. It is one of the most flexible and extensible imaging standard available now and the near future.

JPM

JPM, JPEG 2000 Part 6, is a compound image format for mixed raster content. This is one example of JPEG 2000 extending to other imaging applications: document imaging. JPM is designed for content such as: magazines and newspapers, compression performance with JPM is excellent and whole pages of magazines with images and text can be compressed into a single file.[3]

Compression Performance

JPEG 2000's compression over JPEG at the same bitrate is quite significant at lower bitrate. At the same bitrate, JPEG 2000 has almost a 2.0dB PSNR (Peak Signal to Noise Ratio) over JPEG in tests, or in other words: a 30-50% bitrate reduction for the same quality.[4]

In real world images, JPEG 2000 performance and features exceeds JPEG in many ways. JPEG 2000 has an accurate and flexible rate control system which allows us to easily reduce the compressed data in an accurate manner.

Sample Images

These images are both compressed images. The left has been compressed by JPEG and the right by JPEG 2000. The original uncompressed file size is 900kB, 640x480x24bit per pixel, and both compressed files are 10kB each, 100:1 compression.

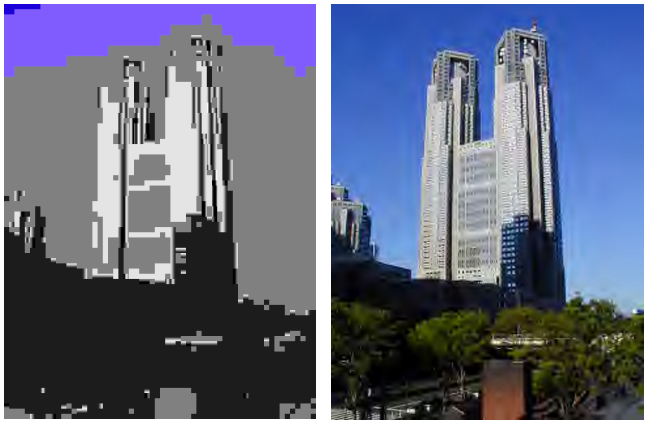

Figure 1. Left: JPEG compressed image; Right: JPEG 2000 compressed image

JPEG 2000 & Document Imaging

JPEG 2000 is highly optimized for a variety of image types. From real photographs, to computer generated imagery, to text, JPEG 2000 Part 6: JPM is a combination of all these types of imagery.

Case Study: The Yomiuri Shimbun & JPEG 2000

In Japan, the Yomiuri Shimbun, founded in 1874 and has headquarters in Tokyo, is one of Japan's largest newspapers with over 10 million newspapers in daily circulation. The Yomiuri Shimbun has deployed JPEG 2000 into their internal workflow with the help of NEC.[5] The old and new workflow and archiving methods are outlined below with analysis.

Pre-JPEG 2000 Workflow

The main source of news is located in Tokyo and each specific region of Japan has their local Yomiuri Branch. To make a newspaper, each of these branches require the main pre-press version from Tokyo along with local stories to produce a full newspaper for the local area. The Tokyo branch would send off pre-print versions of the story with photographs to each local branch for processing via G4 FAX. From this pre-press version from Tokyo each local Yomiuri branch would produce a final copy and distribute.

JPEG 2000 Workflow

With JPEG 2000 system in place in Tokyo and in local branches, the whole system of producing a newspaper at the local branch has become simplified using DocumentSkipper[6] and JPEG 2000 Part 6 for quick image viewing and streaming transfer. Each branch pulls off the data they need from Tokyo through an ISDN (64-384kbps) line, keeping an all digital workflow.

Savings in File Size and Increase in Resolution

With the old method of compression, an A4 monochrome image at 400dpi would be approximately 1.3MB. Using JPEG 2000, they can increase to A3 full color images at 400dpi at the same file size as before. The archived images stored in headquarters are the same as the images streamed to local branches. Seamlessly using the archive version for distribution and production. With a single file distribution and viewing from rapid page flipping, to monitor readable, to print ready, this has all been integrated to one seamless system with JPEG 2000. Figure 2 shows this system flow implemented at the Yomiuri Shimbun.

With JPEG 2000, the Yomiuri Shimbun has enhanced their workflow between headquarters and branch offices, increased the functionality of their archive and saved space while increasing quality. With their archive in JPEG 2000 format, they are also ready to deliver newspaper images over the Internet to readers using the same seamless JPEG 2000 technology.

From this case study, we see that document imaging with JPEG 2000 has reached a new level. Still imagery has advanced to a single: archive, distribution and production format. Now we focus on the next level for another imaging application: moving images.

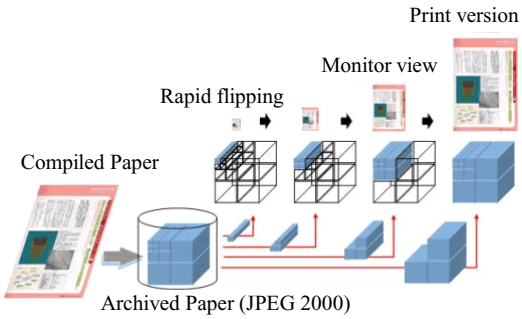

Figure 2. Yomiuri Shimbun Data Workflow

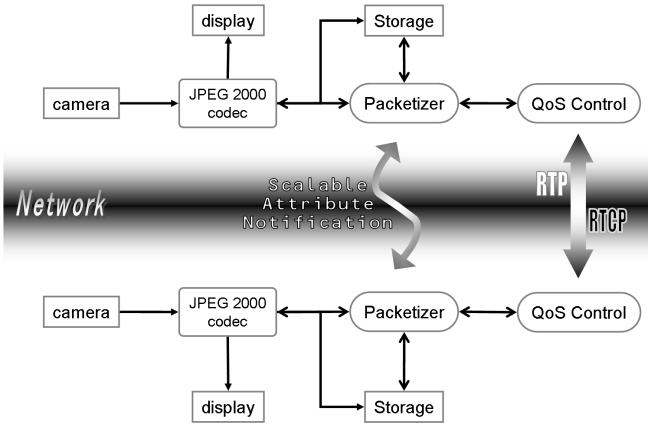

Figure 3. System overview of Arch-BEAM system

JPEG 2000 & Moving Images

JPEG 2000 has a part dedicated to video, JPEG 2000 Part 3: Motion JPEG 2000 or simply known as: MJ2.[7]

On a media, MJ2 represents the format which will hold JPEG 2000 video but when streamed on the network, another standard is in development: JP2RTP.[8] This is to standardize JPEG 2000 for real-time transfer over a network, also known as JP2RTP. This is currently standardizing within the IETF, Internet Engineering Task Force, and on track to become an open standard. JP2RTP is standardized to realize scalable delivery and real-time communication to maximize JPEG 2000 functionality.

In a previous paper,[9,10] BLITZ was introduced as a scalable streaming video solution using JPEG 2000. BLITZ is a video on demand scalable server using JP2RTP.

Arch-BEAM is a complete capture, encode, storage, and delivery system in addition to all of BLITZ's functionality and more. Arch-BEAM handles HD-SDI input and standard video input and a JPEG 2000 encoder board to deliver video. As Arch-BEAM is also developed to be a two-way communication system, Arch-BEAM supports encoding and decoding of JPEG 2000 bitstream.

Arch-BEAM

BEAM Group in the Information Technologies Laboratories of Sony has been dedicated to develop a robust & high quality video communication system. During development, we understand archiving has a particular set of requirements and JPEG 2000 fulfills those requirements and more. Through Arch-BEAM and JPEG 2000, scalable delivery of video archives becomes very trivial.

Figure 3 shows the overview of Arch-BEAM, an implemented real-time video communication system, which realizes not only a one-way streaming application but also two-way interactive video transmission such like TV conference and TV phone.

At the input, raw video is captured and compressed by the video codec. Since each frame is encoded independently within its own frame, JPEG 2000 is the ideal video codec for Arch-BEAM system. In addition to the still-image features of JPEG 2000, there are many other factors when applying these features to video:

Error resilience: The feature of error resilience lies not only in the error resilient code itself, embedded in the bit-stream, but also in the intra frame coding.

Intra frame coding: you can avoid error propagation between frames of video when you code each frame independently of each other unlike inter-frame coding techniques.

Low compression delay: Another factor that we consider is JPEG 2000's low coding delay. Less than just 1.5 frame delay, or about 50ms, can be seen for the encoding process on our system.

Compression performance for video: Since the receiver can have resolutions varying from: high definition TV, standard definition TV, personal computer, personal digital assistant, or mobile phone, the sender needs to parse required data from all the layered data to match the different resources of clients. To do that efficiently, we propose new RTP (Real-time Transport Protocol) packet format to satisfy such service on the packetizer module, providing the indication of priority for each packet and scalable requirements.

Arch-BEAM is not just an implementation of JPEG 2000 for network video. Arch-BEAM has more technologies to enhance the real-time network video quality without having to introduce additional constraint on the network. Focusing on keeping real-time constraints and high quality video on the receiver, various control techniques are supplied in the QoS (Quality of Service) Control module: network status monitoring, rate control, Forward Error Correction (FEC), and Real-time-ARQ™ (Automatic Repeat reQuest).

In this system, RTP[11] above UDP (User Datagram Protocol) is served as the transport protocol for the network multimedia application while RTCP (Real-time Transport Control Protocol) is accompanied to convey the feedback information for the sender to monitor the network status and adjust the control techniques to adapt to the network conditions. Loss prediction based TCP-friendly Congestion Control[12,13] is proposed to react to the network congestion in the early stage and smooth the rate of the video data. In the application layer, FEC and Real-time-ARQ™ are adaptively selected or combined to recover the lost packets at a maximum. When the RTT (Round Trip Time) is small, Real-

time-ARQ™ is activated to recover the lost packets. As RTT increases and exceeds a given threshold, FEC becomes the dominant error control for the real-time video communication.

With Arch-BEAM and BLITZ, archive video can be taken to a new level: real-time archiving and distribution. As you capture your video in JPEG 2000, Arch-BEAM system can archive and/or distribute the video in a scalable manner in real-time (see Figure 4). No need for processing or reformatting for various clients and bandwidths, Arch-BEAM will process for each client simply on-the-fly.

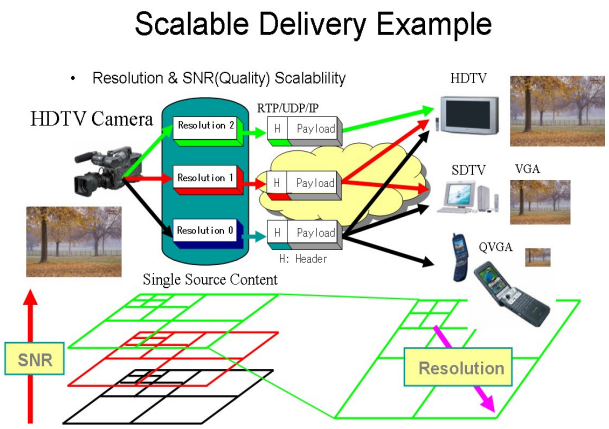

Figure 4. Scalable Delivery Example

This technology is especially useful in an informal basis, particularly for in-house presentations and guest lecturers. The capture can be archived which will be there for on-demand viewing later or the capture can be simultaneously streamed to clients immediately. As we move towards a digital world with all media live and online all the time, the benefits of educational institutions employing a real-time archiving format become phenomenal in access and usage on the Internet and for institutions' own archives.

Arch-BEAM provides the next step in real-time streaming video with on-the-fly archiving and scalable distribution. This would bridge the gap between archive video and distributed video into a single format. From high resolution capture to low resolution personal video players, Arch-BEAM can handle all resolutions with a single source. Even over different communication links, the data load can be easily balanced for efficient and effective delivery.

Unified Image and Video Codecs

JPEG 2000's features in still image coding translate directly to other imaging applications which extend from it such as: document imaging and moving pictures. With the adoption of JPEG 2000 as an archive format for imaging, document imaging, and video in archiving, archives will have a single codec supporting three major imaging applications. A single core codec with different extensions for major imaging application allows for simplified development and implementation. As soon as you have a platform for still image viewing, extending to document imaging and video is a simple step compared with supporting a different codec for each application.

As advances in the JPEG 2000 codec moves forward, benefits to all other imaging applications extending from JPEG 2000 will or may benefit directly as they share the same core codec. Leaving JPEG 2000 development to occur independently of the application allows more important and interesting application extensions to be done; such as extending JPEG 2000 to 3D mapping and the preservation of real objects in the digital domain using JP3D.[14]

Shared Resource

Another area JPEG 2000 will be used is digital cinema. Currently, the Digital Cinema Initiative (DCI) has chose JPEG 2000 to be the distribution format for digital movies.[15,16] JPEG 2000's compression performance, scalability, security, and extensibility are key features in this decision. As digital cinema titles increase, so will equipment, users, support, and tools. At the same time, sharing the same base image codec with DCI allows for increased resources and copies of distribution masters between each other to be shared instead of institutions re-mastering on their own.

This flow of resources between institutional archives and studios leverages larger resources for each and allow for better: interchange, codec support, tools, server resources, and end-user base. As each grows, not only will material flow between each other easily but tools created for one can be used simply in the other.

Conclusion

Using JPEG 2000 for both archive imagery and video brings new advantages more than just more images in the same storage but simplified codec support, extensibility to other aspects of image archiving and scalable distribution. A shared format with digital cinema also brings shared resources and support with another important and resourceful organization. JPEG 2000's scalability brings a wealth of new features such a network transport, scalablity to any device no matter what resources are available and unified archive and distribution formats.

JPEG 2000's flexibility allows for archiving of still imagery, document images, video, and more. The Yomiuri Shimbun has stepped their production to a new level thanks to JPEG 2000's features and ease of implementation. They have a simpler workflow with better compression and a unified archive and production format in use now. Savings in storage and production time is immediate and in the future as whole newspaper images are delivered on the network, the Yomiuri Shimbun already has the infrastructure.

The next step is to have similar functionality in video and it can be done in many ways through MJ2 and through a real-time streaming method found in JP2RTP or Arch-

BEAM. Arch-BEAM using JPEG 2000 allows for real-time streaming of video and instant archiving and distribution and real-time archiving.

JPEG: the consumer codec. JPEG 2000: the professional codec that scales to the consumer level. With JPEG 2000, digital archiving and distribution can be unified into a single format for simple and unified digital archiving and distribution.

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Biographies

Andrew Leung received a B.Sc Electrical Engineering from the University of Alberta in 2001. He is currently a researcher of BEAM Group, Information Technologies Laboratories, Sony Corporation specifically focused on JPEG 2000 applications and implementations for Archiving and Medical Systems. Currently, he is focused on promotion of JPEG 2000 for Archiving and applying JPEG 2000 to medical systems and related developments. Andrew is an avid snowboarder and photographer whenever he is not at his desk.

Eisaburo Itakura received his B.Eng in Applied Mathematics & Physics in 1988 and M.Eng in Applied Systems Science in 1990 from Kyoto University, Kyoto, Japan. In 1990, he joined the Corporate Research Lab of Sony Corporation as a researcher. From 1999 to 2000, he was a visiting scholar at the University of Illinois at Urbana-Champaign, U.S.A. Currently enrolled in a doctorate course in the Graduate school of Informatics, Kyoto University; his research interests include audio-visual communication systems over the Internet, and combining QoS and codec technologies. He is currently a researcher and senior manager of BEAM Group at Information Technologies Laboratories of Sony Corporation.