Using Compression Techniques to Streamline Image and Video Storage and Retrieval

To overcome large-scale digital media content challenges, organizations need a compression strategy that balances storage and transmission costs with image quality and business requirements.

Executive Summary

Digital devices such as smartphones and tablets have changed the way in which we live and interact. This channel has paved the way to digitize virtually all work and play operations and activities. Companies across industries now digitize operational and process-oriented content, image and video form, in applications ranging from surveillance systems to identity management.

The impact is already being felt in industries as diverse as media and entertainment, online retail and social networking. With the rapid development in mobile technology, users now want quality digital content to be delivered to these new digital channels. Accommodating these demands means delivering images and videos on a large scale in a timely way.

This white paper illustrates the challenges that all industry players face in handling large-scale digital media content. Importantly, it proposes a generic solution architecture to help organizations industry-wide to achieve efficient digital media storage and transmission.

Digital Content Challenges

To meet customers’ increasingly digital content demands, organizations need more cost-effective and secure ways to store, retrieve and share assets. The cost of warehousing digital content increases exponentially with the size/scale of the organization. As such, bigger companies incur greater costs to warehouse digital content.

The Bottom Line

The storage and transmission of digital images and video has proven to be very expensive. Figure 1 shows the size of a standard definition (720 X 480 X 24bit) video of one hour’s length.

For example, a standard definition video of 100GB+ costs roughly $252 per year to store and transmit via a cloud service such as Windows Azure. The cost could run into hundreds of thousands of dollars when hours of videos or thousands of uncompressed images in terabytes are stored. The transmission cost and time of such uncompressed data is additional overhead, since it requires gigabytes of bandwidth. In the case of high definition (1920 X 1080) video, the
uncompressed file size can be multiplied nearly five times and becomes too large to cost-effectively store and transmit. Here is where compression is required. For example, 112GB of video can be reduced to 50GB or less based on the exact components of an effective compression strategy.

The Need for Effective Storage
Digital content handled across industry sectors such as for surveillance systems is solely for reference. Therefore, it does not demand high-definition output for storage or retrieval. This means organizations can compromise content quality for storage.

However, this is not the case in other sectors, such as healthcare. These organizations deal with radiographic images and surgery videos. Content quality in these applications cannot be compromised as it concerns critical data. Such sectors demand cost-effective but high-quality data storage and retrieval.

Storage solutions in the media and entertainment industry require the best of both worlds. It may not be appropriate to broadcast the same quality content over a wide range of devices, because certain digital media content is created with specific devices in mind ranging from smartphones to high-definition televisions. To understand this balance, the quality of the content delivered should be based on the following:

• Bandwidth available at the target device.
• Maximum quality that the device supports.

Therefore, applications that deliver targeted digital content require variable quality retrieval procedures from the same stored media content.

The Image Compression Approach
Strictly defined, video is comprised of a sequence of images flowing at a fast transmission rate (as measured in number of frames/images per second). Therefore, both image and video compression comes down to precision image compression. However, video compression follows an additional routine that includes inter-frame compression, motion estimation and motion compensation. Organizations, therefore, must choose the most appropriate approach for video and image to achieve a desired compression rate.

Cost-effective media content storage can be accomplished by using efficient image compression techniques. As mentioned earlier, divergent usages may require different image compression techniques. The level of compression (size reduction) also depends on the specific business need.

A counterpart operation of the coding (compression) executed at the transmitter side is decoding (decompression), which is performed at the retrieval/receiver end as a part of the image compression procedure. Depending on the media device, user need, transmission bandwidth and its application, the decoder may vary the quality of the digital media content.

Two Approaches
As mentioned above, a video stream can be viewed as a sequential image stream. Therefore, video coding can be accomplished through image coding with additional processes like inter-frame compression, motion estimation and motion compensation. In image codec terminology, an image is known as a frame. The approach to compressing a frame or a sequence of frames can be viewed through two windows:

• **Intra-frame compression**: This technique considers each frame as a non-correlated segment of an image sequence and reduces only the spatial (pixel) redundancies present in an image.
• **Inter-frame compression**: This technique considers each frame as part of an image sequence and employs temporal predictions,
thus aiming to reduce temporal and spatial (pixel) redundancies. This also increases the efficiency of data compression.

Video compression algorithms generally aim for an inter-frame compression technique, because a video stream may have high-ratio temporal redundancies, while an image compression routine will apply an intra-frame compression technique. In addition to inter-frame compression, video coding also follows motion estimation and compensation procedures that are explained in the following sections.

**Types of Compression**

Regardless of whether it is image or video, the compression type is broadly classified into two classes: lossy or lossless. The appropriate type of compression that is followed is based on the nature of the application.

- **Lossless compression**: Applications that mandate zero loss in the quality of images and videos upon archiving require the lossless compression technique. Examples are found in healthcare industries which deal with radiographic images and manufacturing industries which use machine drawings images and whose intricate details are significant. Similarly, images of circuit diagrams, etc. are another example that demands zero loss in quality and hence use the lossless compression technique.

- **Lossy compression**: Applications that do not require high fidelity in image and video quality are typically archived using lossy compression techniques. The acceptable loss in quality is determined by the use case. A common example of lossy compression relates to images and videos captured by digital cameras or mobile phones, in which data from the image sensor is processed to a compressed format of either GIF or JPEG of desired quality. Lossy compression can reduce the size of the digital content from 5% to almost 95%, depending on the business requirement. Though called “lossy,” they are often termed as visually lossless compression.

**Implementation Details**

As depicted in Figure 2, each block in the implementation phase applies a discrete algorithm that is contingent upon the application, approach and the type and level of desired compression. Any digital image is viewed merely as a two-dimensional matrix in a spatial domain. The compression algorithm transforms the image, or frame, to a different dimension and domain, in which individual components of the image can be analyzed. Post analysis, redundant image components are quantized and the image matrix is encoded by using lossless or lossy compression techniques. The encoded image stream is converted into compressed (encoded) digital bit streams, which are used for transmission or storage.

In the event that the system handles a sequence of images or video streams, motion estimation and compensation algorithms come into play. These components analyze the current frame...
with that of the previous frame from the memory and calculate the redundant elements that are inappropriate for further processing.

For instance, consider a video stream of about one hour from a surveillance system, which predominantly records an empty aisle with sparse passers-by. Such an uncompressed video stream constitutes more than 100 GB of disk space, which can be expensive to store, transmit and handle. Efficient image compression routines help in reducing cost and minimizing the required disk space, which speeds transmission due to lower bandwidth requirements. In our example of a surveillance video of a mostly empty aisle, most of the video stream is comprised of the same content (i.e., empty aisle). Therefore, frames indicating the empty aisle may be considered redundant and can be encoded into a single frame present at multiple instances. The motion estimation and compensation algorithm reads that the frames are repetitive and responds only to the changes that may be present between the frames, ignoring the redundant components.

Tangible Benefits of Compression Techniques

- Among the prime advantages of image/video compression is size reduction. Based on the application, an image/video stream can be compressed to the required size, which can eventually save storage space. Therefore, it is cost-effective. For situations that involve large amounts of data, this generates significant impact, optimizing archiving and producing appreciable cost savings.

- Another advantage is the variable quality retrieval procedure. This is also referred to as progressive resolution encoding. Some image/video playback devices do not support high-resolution data streams or may restrict the bandwidth through which the content is delivered. This prevents streaming of uncompressed high-quality data over such devices. In such cases, image decoder (decompression) can be tuned to deliver appropriate data quality from the compressed stream.

- Transmission of compressed digital media content between electronic devices or Web hosts and the device’s retrieval rate is faster, thereby improving the workflow of the process.

Compression Au Courant

New modes of image compression techniques are emerging that could reduce costs for many industries such as online retailing and market researchers whose businesses pivot around huge image volumes. Other industries such as media and entertainment could also embrace new compression techniques to achieve greater efficiency. Consider the example of the surveillance system. The hours of surveillance video recording and thousands of photographic images for identity management (which are stored for mere reference) occupy large volumes (in terabytes) of server space. Similar scenarios prevail in online commodities businesses, where millions of company-supplied, user-shared product images of products are stored on its e-commerce servers.

Market Insight

- A popular graphically-rich iOS Twitter client app, Tweetbot, which weighs over 33MB, uses over 26MB to stock more than 900 images that are compressed using a native iOS IDE compression technique. Such a large image size slows image display time. Beyond this elementary level compression, the app is integrated with additional compression techniques to achieve a compression rate of more than 80% and a display time that is reduced by a factor of three (see Figure 3).

Compression Analytics

<table>
<thead>
<tr>
<th>Compression Technique</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncompressed</td>
<td>49.63 MB</td>
</tr>
<tr>
<td>Native Compression – iOS IDE</td>
<td>26.46 MB</td>
</tr>
<tr>
<td>Lossless Compression Technique</td>
<td>16.81 MB</td>
</tr>
<tr>
<td>Lossy Compression Technique</td>
<td>9.37 MB</td>
</tr>
</tbody>
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Figure 3
• A popular camera-capturing app on iOS, IncrediBooth, was 70MB in size and had PNG images of screen texture with a resolution of 2048 X 1536, each weighing more than 10MB in its app bundle. The bundle size was shrunk from 70MB to 31MB (a reduction of more than 50%) by incorporating effective lossless image compression techniques.

• Experimental results in healthcare show that medical imaging (such as Dicom, CT, MRI, etc.) can be optimized using compression schemes that retain image quality only in the region of interest (i.e., in diagnostically important regions) and reduce image size by more than 95%.

• A Netherlands-based medical imaging systems firm, Accusoft, has implemented lossless JPEG compression and decompression schemes to achieve image quality comparable to the original image. A typical 2048 x 2048 resolution 16-bit grey scale image of size 9,948 KB was reduced to 5,517 KB (more than 40% compressed) using lossless compression techniques.

Looking Forward

When a state-of-the-art image compression strategy is embraced, companies can save on storage and transmission costs. Similarly, retrieval rates can also be increased, thereby providing fast and effective solutions to users inside and outside the company. The ratio of the storage savings is directly proportional to the level of compression and the quality required upon retrieval.

When it comes to digital content management, every block in the implementation workflow plays a vital role in warehousing it effectively. An effective algorithm is required for each block for efficient repositioning.

To achieve cost-effective warehousing and transmission of digital media content, organizations must analyze the level of quality/compression required by the business. The resulting solution should then be capable of handling multiple images and video formats as required by the business.

The compression techniques selected should be framed and optimized to achieve the required compression rate at the desired data quality, without incurring any additional overhead. Finally, if the business targets multiple devices for content delivery, then the decoder (at the device end) must be modelled to deliver progressive quality based on the device specification.

Footnotes

About the Author

Srinivasan Krishnan is an Associate with Cognizant’s Audio Video Imaging Center of Excellence within the company’s Global Technology Office. He has over four years of architecture design, algorithm development and application-building experience and has extensive experience developing solutions in niche domains such as digital image processing, computer vision and machine learning. He holds a bachelor’s degree in electronics engineering from Anna University and a master’s in microelectronics systems design from University of Southampton in the UK. He can be reached at Srinivasan-5.Krishnan-5@cognizant.com.