AXIS COMMUNICATIONS

WHITE PAPER

DIGITAL IMAGES AND VIDEO
FOR SURVEILLANCE APPLICATIONS

# Compression techniques

 

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# 1. Introduction to compression techniques

***JPEG, Motion JPEG and MPEG are three well-used acronyms used to describe different types of image compression format. But what do they mean, and why are they so relevant to today's rapidly expanding surveillance markets? This White Paper describes the differences, and aims to provide a few answers as to why they are so important and for which surveillance applications they are more suitable.***

When designing a networked digital surveillance application, developers need to initially consider the following factors:

- Is a still picture or a video sequence required?
- What is the available network bandwidth?
- What image degradation is allowed due to compression - artifacts?
- What is the budget for the system?

When an ordinary analog video sequence is digitized according to the standard CCIR 601, it can consume as much as 165 Mbps, which is 165 million bits every second. With most surveillance applications infrequently having to share the network with other data intensive applications, this is very rarely the bandwidth available. To circumvent this problem, a series of techniques – called picture and video ***compression techniques*** – have been derived to reduce this high bit rate. Their ability to perform this task is quantified by the ***compression ratio***. The higher the compression ratio is, the smaller is the bandwidth consumption. However, there is a price to pay for this compression. Because increasing compression causes an increasing degradation of the image. This is called ***artifacts***.
But the dilemma is; the more sophisticated the employed compression technique is, the more complex and expensive the system. This generally makes sophisticated compression restrictive in terms of maintaining low system costs.

In describing the widespread use of different compression techniques, this document presents the associated advantages and disadvantages of each, giving the reader the ability to make decisions that are based on fact, not rumor.

# 2. Two basic standards JPEG and MPEG

The two basic compression standards are ***JPEG*** and ***MPEG***. In broad terms, JPEG is associated with still digital pictures, whilst MPEG is dedicated to digital video sequences. But these traditional **JPEG** and ***JPEG 2000*** image formats also come in flavors that are appropriate for digital video as well; ***Motion JPEG*** and ***Motion JPEG 2000*** formats.

The group of MPEG standards that include the ***MPEG-1***, ***MPEG-2*** and ***MPEG-4*** formats, share some similarities, as well as some notable differences:

One thing they all have in common is that they are all International Standards set by the ***ISO*** (International Organization for Standardization) and ***IEC*** (International Electrotechnical Commission) — with contributors from the US, Europe and Japan among others. They are

also recommendations proposed by the ***ITU*** (International Telecommunication Union), which has further helped to establish them as the globally accepted *de facto* standards for digital still picture and video coding.

The foundation of these standards was started in the mid-1980s when a group called the ***Joint Photographic Experts Group*** (a.k.a. JPEG) was formed. With a mission to develop a standard for color picture compression, the group's first public contribution was the release of the first part of the JPEG standard, in 1991. Since then the JPEG group has continued to work on both the original JPEG standard, and it's later successor: the JPEG 2000 standard.

In the late 1980s the ***Motion Picture Experts Group*** (a.k.a. MPEG) was formed with the purpose of deriving a standard for the coding of moving pictures and audio. It has since produced the standards for MPEG-1, MPEG-2, and MPEG-4. The group's current work is focused on the next generation of standards, called MPEG-7 and MPEG-21. As these standards do not concern themselves with video compression, they are not explained in any further detail within this white paper.

# 3. Image data reduction

As mentioned previously, a digitized video sequence can comprise of up to 165 Mbps of data. To reduce the media overheads for distributing these sequences, the following criteria is commonly employed to achieve desirable reductions in image data:

- Reduce color nuances within the image
- Reduce the color resolution with respect to the prevailing light intensity
- Remove small, invisible parts, of the picture
- In the case of a video sequence, parts of the picture that are unchanged are left as such.

All of these techniques are based on an acute understanding of how the human brain and eyes work together to form a complex visual system.

As a result of these subtle reductions, a significant reduction in the resultant file size for the image sequences is achievable with little or no adverse effect in their visual quality. The extent to which these image modifications are humanly visible, is typically dependent upon the degree to which the chosen compression technique is used.

# 4. An overview of compression techniques

**Figure 1:** *The original picture.*

## 4.1 JPEG

The JPEG standard, ISO/IEC 10918, is the single most widespread picture compression format of today. It offers the flexibility to either select high picture quality with fairly high compression ratio or to get a very high compression ratio at the expense of a reasonable lower picture quality. Systems, such as cameras and viewers, can be made inexpensive due to the low complexity of the technique.

The artifacts show the "blockiness" as seen in Figure 2. Compare it to the original picture in Figure 1. The blockiness appears when the compression ratio is pushed too high. In normal use, a JPEG compressed picture shows no visual difference to the original uncompressed picture.

JPEG image compression contains a series of advanced techniques. The main one that does the real image compression is the Discrete Cosine Transform (DCT) followed by a quantization that removes the redundant information (the "invisible" parts).

**Figure 2:** *A JPEG compressed picture.*

## 4.2 Motion JPEG

A digital video sequence can be represented as a series of JPEG pictures. The advantages are the same as with single still JPEG pictures – flexibility both in terms of quality and compression ratio.

The main disadvantage of Motion JPEG (a.k.a. MJPEG) is that since it uses only a series of still pictures it makes no use of video compression techniques. The result is a slightly lower compression ratio for video sequences compared to "real" video compression techniques.

## 4.3 JPEG 2000

Recently, the successor to the successful JPEG compression standard has seen the light of day. The basis was to incorporate new advances in picture compression research into an international standard. Instead of the DCT transformation, JPEG 2000, ISO/IEC 15444, uses the ***Wavelet transformation***.

The advantage of JPEG 2000 is that the blockiness of JPEG is removed, but replaced with a more overall fuzzy picture, as can be seen in Figure 3.

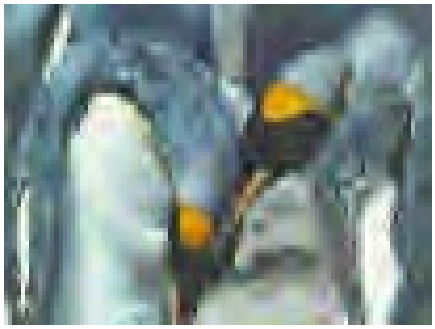

**Figure 3:** *A JPEG 2000 compressed picture.*

Whether this fuzziness of JPEG 2000 is preferred compared to the "blockiness" of JPEG is a matter of personal preference. However, the compression ratio for JPEG 2000 is higher than for JPEG and the difference increases with a higher compression ratio. For moderate compression ratios, JPEG 2000 produces pictures typically about 25% the size of JPEG at equal picture quality. The price to pay is a far more complex compression technique.

## 4.4 Motion JPEG 2000

As with JPEG and Motion JPEG, JPEG 2000 can also be used to represent a video sequence. The advantages are equal to JPEG 2000, i.e., a slightly better compression ratio compared to JPEG but at the price of complexity.

The disadvantage reassembles that of Motion JPEG. Since it is a still picture compression technique it doesn't take any advantages of the video sequence compression. This results in a lower compression ration compared to real video compression techniques.

## 4.5 H.261/H.263

The H.261 and H.263 are not International Standards but only Recommendations of the ITU. They are both based on the same technique as the MPEG standards and can be seen as simplified versions of MPEG video compression.

They were originally designed for video-conferencing over telephone lines, i.e. low bandwidth. However, it is a bit contradictory that they lack some of the more advanced MPEG techniques to really provide efficient bandwidth use.

The conclusion is therefore that the H.261/H.263 are not suitable for usage in general digital video coding.

## 4.6 MPEG-1

The first public standard of the MPEG committee was the MPEG-1, ISO/IEC 11172, which first parts were released in 1993. MPEG-1 video compression is based upon the same technique that is used in JPEG. In addition to that it also includes techniques for efficient coding of a video sequence.

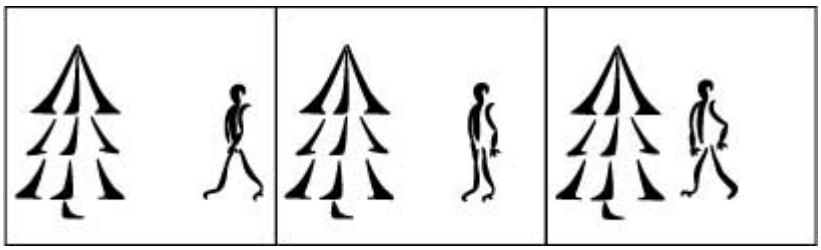

**Figure 4:** *A three-picture JPEG video sequence.*

Consider the video sequence displayed in Figure 4. The picture to the left is the first picture in the sequence followed by the picture in the middle and then the picture to the right. When displayed, the video sequence shows a man walking from right to left with a tree that stands still.

In Motion JPEG/Motion JPEG 2000 each picture in the sequence is coded as a separate unique picture resulting in the same sequence as the original one.

In MPEG video only the new parts of the video sequence is included together with information of the moving parts. The video sequence of Figure 4 will then appear as in Figure 5. But this is only true during the transmission of the video sequence to limit the bandwidth consumption. When displayed it appears as the original video sequence again.

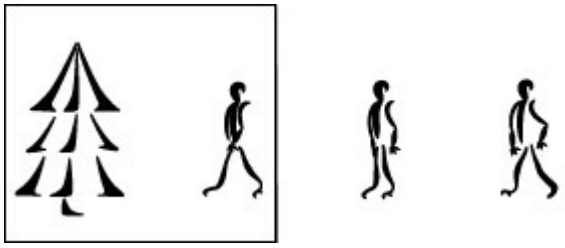

**Figure 5:** *A three-picture MPEG video sequence.*

MPEG-1 is focused on bit-streams of about 1,5 Mbps and originally for storage of digital video on CDs. The focus is on compression ratio rather than picture quality. It can be considered as traditional VCR quality but digital instead.

### 4.7 MPEG-2

The MPEG-2 project focused on extending the compression technique of MPEG-1 to cover larger pictures and higher quality at the expense of a lower compression ratio and therefore also higher bandwidth usage.

MPEG-2, ISO/IEC 13818, also provides more advanced techniques to enhance the video quality at the same bit-rate. The expense is the need for far more complex equipment. Therefore these features are not suitable for use in real-time surveillance applications.

As a note, DVD movies are compressed using the techniques of MPEG-2.

### 4.8 MPEG-4

Also the third generation of MPEG is based upon the same technique. Once again, the new project focused on new application usages.

The most important new features of MPEG-4, ISO/IEC 14496, concerning video compression are the support of even lower bandwidth consuming applications, e.g. mobile units, and on the other hand applications with extremely high quality and almost unlimited bandwidth. The making of studio movies is one such an example.

Most of the differences between MPEG-2 and MPEG-4 are features not related to video coding and therefore not related to surveillance applications.

## 5. MPEG comparison

All MPEG standards are back compatible. This means that an MPEG-1 video sequence also can be packetized as MPEG-2 or MPEG-4 video. Similarly, MPEG-2 can be packetized as an MPEG-4 video sequence.

The difference between a true MPEG-4 video and an MPEG-4-packetized MPEG-1 video sequence is that the lower standard does not make use of the enhanced or new features of the higher standard.

Since both MPEG-2 and MPEG-4 covers a wide range of picture sizes, picture rates and bandwidth usage, the MPEG-2 introduced a concept called ***Profile@Level***. This was created to make it possible to communicate compatibilities among applications. For example, the Studio profile of MPEG-4 is not suitable for a PDA and vice versa.

The comparison of the MPEGs in Table 1, contains the MPEG-1 with its most often used limitation (Constrained Parameters Bitstream, CPB), MPEG-2 with its Main Profile at Main Level (MP@ML), and MPEG-4 Main Profile at L3 Level.

| **MPEG** | **1** | **2** | **4** |
|---|---|---|---|
| Max bit rate (*Mbps*) | 1,86 | 15 | 15 |
| Picture width (*pixels*) | 352 | 720 | 720 |
| Picture height (*pixels*) | 288 | 576 | 576 |
| Picture rate (*fps*) | 30 | 30 | 30 |

**Table 1:** *MPEG comparison.*

Neither Motion JPEG nor Motion JPEG 2000 specifies maximal picture size or rate or bandwidth usage.

# 6. Conclusion – Still Pictures

For single still pictures both JPEG and JPEG 2000 offers good flexibility in terms of picture quality and compression ratio. While JPEG 2000 compress slightly better then JPEG, especially at very high compression ratios, the momentum of the advantage compared to the price to pay for the extra complexity, makes it a less preferred choice of today.

To state it in another way: The advantages of JPEG 2000 are in compression at very high compression ratio. But then the picture contains very little information and is therefore not suitable for surveillance of any kind.

The advantages of JPEG in terms of inexpensive equipment both for coding and viewing makes it the selection for still picture compression.

# 7. Conclusion – Motion Pictures

Especially the Motion JPEG is a good choice when use in many applications due to its simplicity. This ensures inexpensive equipment at the cost of slightly higher bandwidth consumption. For more efficient bandwidth usage some of the true motion picture compression standards are preferred.

MPEG–1 can be more effective than MJPEG, but for just a slightly higher cost, MPEG–2 provides some advantages supporting better image quality - comprising of frame rate and resolution - but requires more network bandwidth consumption and is a technique of greater complexity. MPEG–4 is developed to offer a compression technique for applications demanding less image quality and bandwidth. It is also able to deliver video compression similar to MPEG–1 and MPEG–2, higher image quality at higher bandwidth consumption.

Since the H.261/H.263 recommendations are neither international standards nor offers any compression enhancements compared to MPEG, they are not of any real interest.

# 8. Acronyms

The following is a description of the acronyms used in this white paper.

**Interlaced** – A technique used in old television system where the picture is divided into two half pictures containing every other line each. When displayed, first the odd lines are displayed then the even lines followed by the odd lines of the next picture and so on. This is the opposite of *Progressive Scan*.
**Progressive Scan** – Each picture in the video sequence is the full picture displayed all in once. This is the opposite of *Interlaced*.
**PAL** – Phase Alternating Line. This is the standard for the analog television format used in Europe with 625 lines at 50 half-pictures per second, i.e. *Interlaced* video.
**NTSC** – National Television Standards Committee. This is the standard for the analog television format used in the US with 525 lines at near 60 pictures per second, i.e. *Interlaced* video.
**CCIR 601** – A standard for digital video for picture size of 720 × 485 at 60 interlaced pictures per second or 720 × 576 at 50 interlaced pictures per second.
**CIF** – Common Intermediate Format. Video of picture size 352 × 288 at 30 pictures per second.
**QCIF** – Quarter CIF. Video of picture size 176 × 144 at 30 pictures per second.
**HDTV** – High-Definition Television. A standard for television of picture size 1920 × 1044 at 30 pictures per second.
**DVD** – Digital Versatile Disc. A standard to store digital audio and/or video on a CD-sized disc.
**MPEG** – Motion Picture Experts Group. The committee responsible for developing the MPEG standards. Homepage at: www.mpeg.telecomitalialab.com
**JPEG** – Joint Photographic Experts Group. The committee responsible for developing the JPEG and JPEG 2000 standards. Homepage at: www.jpeg.org
**ISO** – International Standards Organization. A worldwide federation of national standards bodies from some 140 countries. Homepage at: www.iso.ch
**IEC** – International Electrotechnical Commission. International Electrotechnical Commission. An international standards and conformity assessment body for all fields of electro technology. Homepage at: www.iec.ch
**ITU** – International Telecommunications Union. An international organization within the United Nations System where governments and the private sector coordinate global telecom networks and services. Homepage at: www.itu.int

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