

Determining Video Quality

by Jack Cabasso

Probably one of the most confusing issues I have encountered in my discussions with security professionals is the topic of video quality comparisons. A lot may be attributed to an oxymoron or two

created by the English written language. After all, we speak of high "resolution" cameras, or high "resolution" images. So one would be apt to assume the word "resolution" is synonymous with qual-

ity. We all know what happens when one assumes though. Unfortunately, resolution in video terms does not equate to quality. This begs two questions; what is resolution, and if not quality, what is?

Video Glossary

The first order of business to put all the pieces of the puzzle together is a quick video definitions lesson.

Bit: a binary digit taking a value of 0 or 1 and the basic unit of measure for digital information storage.

Bitrate: the number of bits processed per unit of time (not distance), quantified as bits per second (bps) or in larger increments kilo bits per second (kbps), mega bits per second (Mbps), giga bits per second (Gbps) or tera bits (Tbps).

Codec: a program which encodes (compresses) a digital stream for transmission, storage and encryption and/or decodes a digital data stream for displaying and editing **Compression/Decompression**.

Common Intermediate Format (CIF): Defines the resolution in terms of width and height of the video frame and the frame rate. CIF is stated as 352 x 240 pixels in the NTSC (**N**ational **T**elevision **S**ystem **C**ommittee - used in North America) format. Other common resolutions are: 2CIF (704 x 240), 4CIF (704 x 480). This should not be confused with Common Image Format, a standard frame size for digital video.

Compression Artifact: the result of a significant data compression scheme applied to an image, audio, or video which discards some critical data that may be too complex to store in the available data-rate, or may have been incorrectly determined by an algorithm to be of minimal value.

Image: a two-dimensional artifact.

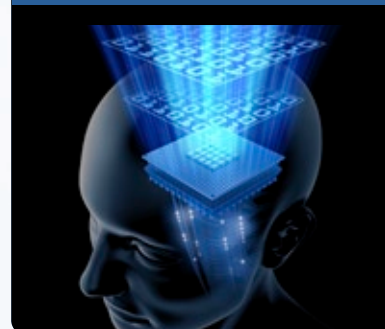
Pixel: (**p**icture **e**lement) is the smallest portion of information in an image. Pixels are merely samples of original images.

Resolution: distinct number of pixels in each dimension that "**MAY**" be displayed. Resolution can be specified as the number of pixel-columns (width) by the number of pixel-rows (height).

Sample: a set of values at a point in time and/or space.

TVL (TV Lines): Method of defining resolution in analog video.

Knowledge You Need



Video Glossary

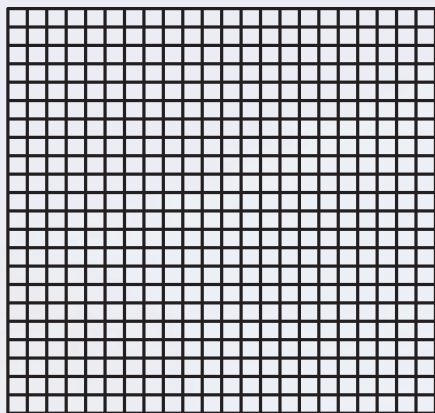
- Bit
- Bitrate
- Codec
- Common Intermediate Format (CIF)
- Compression Artifact
- Image
- Pixel
- Resolution
- Sample
- TVL (TV Lines)

Resolution Does Not Define Quality

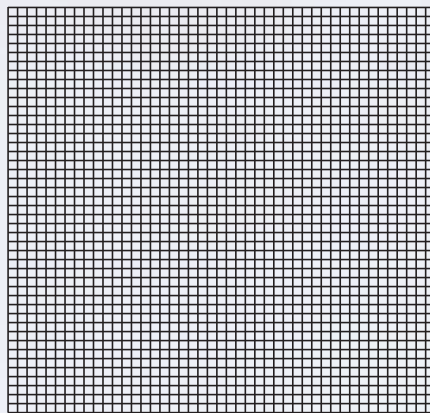
The resolution is the number of pixels that **"MAY"** be displayed, not that **"ARE"** displayed. Therefore, you should think of resolution as a piece of graph paper. All you have to start with is a bunch of empty boxes; which would equate to

pixels. This is the true definition of resolution. CIF resolution would be analogous to a piece of graph paper with 352 boxes wide by 240 boxes high (although a pixel is not perfectly square). A 4CIF image would be a piece of graph paper

with 704 boxes wide by 480 boxes high. Since there are no *"bits"* of information in these boxes yet the resolution just tells you the number of pixels that **"MAY"** be displayed.



CIF



4CIF

Bitrate Equals Quality

What actually is a key determining factor but not the only consideration in quality is the "bitrate." Bits are the information to be inserted into the pixels and the bitrate is the rate of time at which those bits of information are placed into the pixels. The more information or bits applied to the pixel, the denser the image and the higher the quality should be if all other factors are equal. Think in terms of a printer, the more dots-per-inch, the sharper the image. So when you ask someone what is the video quality requirement and they say 4CIF, ostensibly they have not advised you of any "visual" aspect of the quality.



4CIF (Low Bitrate)

CIF (High Bitrate)

"Resolution is the number of pixels that **"MAY" be displayed"**



"Not that are displayed"

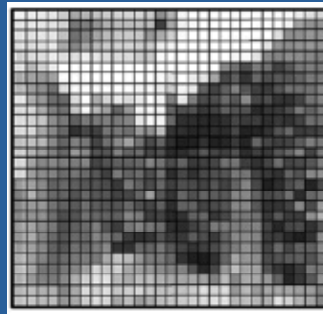
"More bits of data applied means higher image density and resulting quality"



CIF vs. 4CIF

So what is the difference in “potential” quality of CIF vs. 4CIF? Resolution quantifies only how close pixels or lines can be to each other and still be visibly resolved. A 4CIF image “can” potentially produce a better quality image than a CIF image because the more pixels used to represent an image; the closer the result can resemble the original.

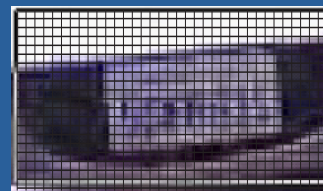
It does not necessarily have to be the case though as 4CIF does not mention the amount or quality of the data to be displayed in the pixels. Accordingly, a CIF image filled with more bits and higher quality bits than a 4CIF image “can” and will produce better visual and audible results. Other considerations vis-à-vis bitrate need to be accounted for to determine the potential video quality.



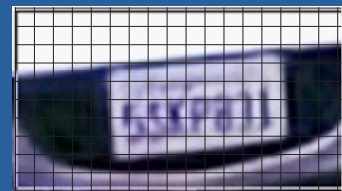
CIF (Low Bitrate)



4CIF (High Bitrate)



4CIF Low Bitrate



CIF High Bitrate

Bitrate depends upon several factors:

- The original material may be sampled at different frequencies
- The samples may use different numbers of bits
- The data may be encoded by different schemes
- The information may be digitally compressed by different algorithms
- The information may be digitally compressed to different degrees

How Codecs Affect Video Quality

So if all things are equal (which is rarely the case) a higher bitrate image with a higher resolution “may” produce a higher quality image than a lower bitrate image with a lower resolution. Once we have determined bitrate the next primary factor to consider is the Codec being applied and the quality of the resulting data.

Video in its raw uncompressed format is typically too large to accommodate for purposes of

storage, transmission and broadcasting. In order to create efficiencies trade-offs are made between minimizing the bitrate by compression and maximizing the recorded quality. Programs called “codecs” are used to accomplish the task.

In digital video to reduce the bitrate a “lossy” compression codec is utilized. A lossy compression is a method which discards some of the information or data which is not criti-

cal to the scene, thus resulting in a lower bitrate. When lossy data compression is used on audio or visual data, differences from the original signal are introduced since data has been discarded. If the compression is too aggressive it becomes noticeable in the form of compression artifacts, which appear in the form of blocky mosaic images. Whether these affect the perceived quality, and, if so how much; depend on the compression

“If compression is too aggressive it becomes noticeable in the form of blocky images.”



scheme, encoder power, characteristics of the input data, the viewer's perception and familiarity with artifacts.

Some codecs are more efficient than others at compressing data. Earlier encoding technologies date back more than half a century (Huffman algorithm), which surprisingly enough although not very efficient are still used today.

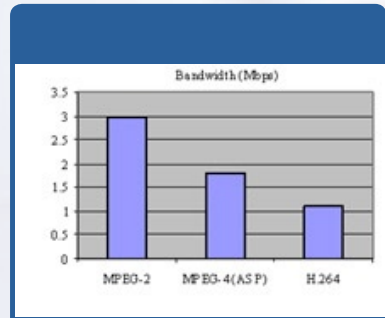
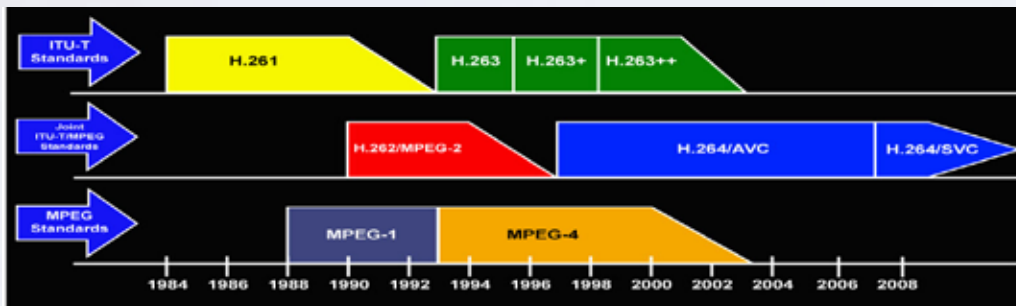
Newer state-of-the-art codecs, such as H.264, take advantage of the more modern arithmetic algorithms. The result is higher quality images at lower bit rates com-

pared to the legacy codecs (MPEG1, MPEG2, MPEG4 Part 2, H.261, H.262 and H.263)

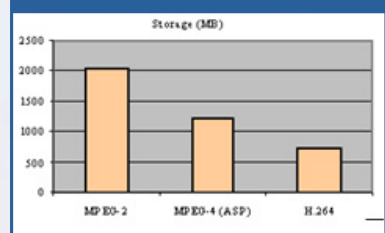
H.264AVC is the first of what are known as "complex" codecs, which can yield up to 50% better compression than MPEG2 and up to 30% better than MPEG4. Better compression means lower bandwidth requirements and faster downloads times. Also, the resulting H.264 video quality is up to 40% superior than MPEG2 and MPEG4.

Complex codecs have various other attributes that make them more

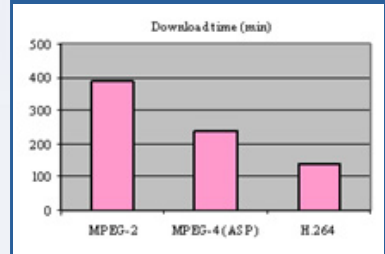
"intelligent" and capable of dealing with unique situations relative to security. For example, pan-tilt-zoom ("PTZ") cameras are commonplace in the surveillance world. When swinging the PTZ cameras older codecs tend to have difficulties in analyzing and processing the scene content either intelligently or quick enough and as such compression artifacts are prevalent and at times may be severe. H.264AVC has several unique characteristics not available in predecessor codecs, which enable it to stabilize fast moving images.



Bandwidth



File Size



Download Time

“Modern codecs compress video more efficiently, resulting in higher quality images with accompanying smaller file sizes”

| | | Standards | | |
|--|---|-------------|-------------|-----------------------|
| | | MPEG -2 | MPEG-4 | H.264 |
| Features | I,P, B-frames | ✓ | ✓ | ✓ |
| | Interlace | ✓ | ✓ | ✓ |
| | Coding | Huffman | Huffman | Huffman or Arithmetic |
| | Block size | fixed 16x16 | fixed 16x16 | variable down to 4x4 |
| | 1/4 pixel | | ✓ | ✓ |
| | GMC | | ✓ | |
| | Loop Filter (aka deblocking filter) | | | ✓ |
| | Slice-based motion prediction | | | ✓ |
| | Multiple reference frames | | | ✓ |
| | MB AFF (improved interlaced management) | | | ✓ |
| | RDO (Rate Distorrtion Optimisation) | | | ✓ |
| WP (Weighted Prediction) | | | ✓ | |
| Switching pictures(for fast chang channel) | | | ✓ | |

Compensating for Extreme Motion

In order to compensate for extreme motion, whether it is from the movement of a camera or just plain old fast moving objects, bitrates are elevated to extreme levels to try to introduce as much information into the image as possible.

Unfortunately, massive bitrates means massive

file sizes and subsequent storage and processing issues. Regardless, even at extremely high bitrates the older codecs for the most part are not capable of stabilizing fast changing scenes. This is something you can easily test for yourself on your DVR or NVR. So forget about what the manufacturers' specifications

say, try it for yourself; seeing truly is believing.

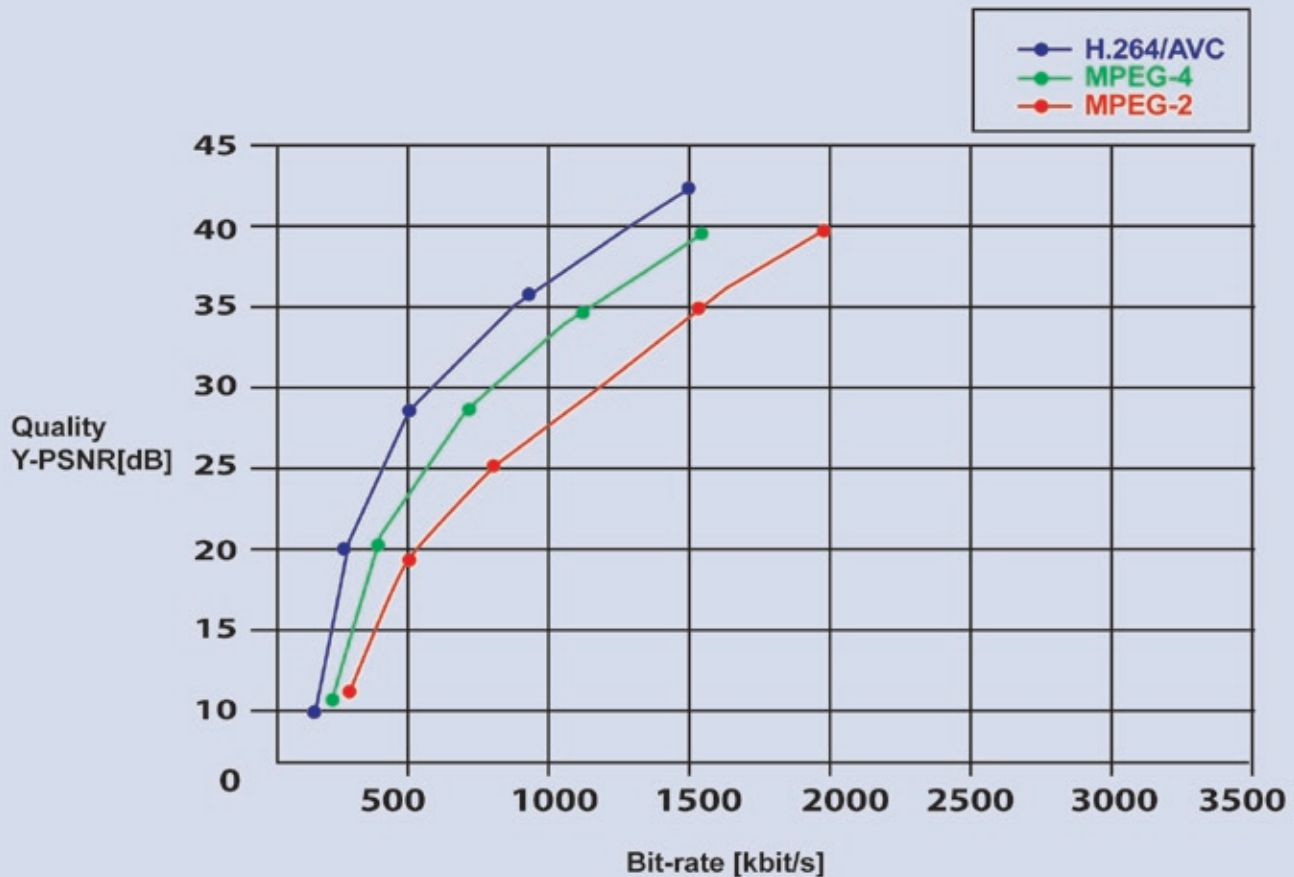
Accordingly, if we say bitrate equals quality and 2 video files are using the same bitrate, one might be better than the other as a result of a more efficient codec. An H.264 video clip recorded at 2Mbps might look substantially

better than an MPEG2 video clip recorded at 2Mbps due to its efficiencies. In fact, since we say that H.264 compresses video more efficiently, a 1Mbps H.264 image, may look better than an MPEG2 or MPEG4 image recorded at as much as 2Mbps.



A 1Mbps H.264 image, may look better than an MPEG2 or MPEG4 image recorded at as much as 2Mbps.

Comparison to **MPEG-2**, **MPEG-4**, and **H.264/AVC**



While this may appear to be the end of the story there are other caveats. We now know the following:

- Resolution is nothing more than the number of pixels to be filled with data
- Bitrate is the key determining factor in what actually determines the video quality
- A higher resolution image (4CIF) does not guarantee a better image than one with a lower resolution (CIF)
- Some codecs can provide higher quality images and smaller files sizes than others

It appears then that the formula for determining the ultimate video quality is:

High Resolution + High Bitrate + Best Codec = Best Quality

Average Storage Rate

Many people ask at what bitrate am I going to get the best image on a specific codec. The subject is quite debatable and you will get arguments from both

sides of the aisle, as manufacturers would have you believe they are capable of providing the highest quality images at some incredibly low bitrates. A lot has to do with

the amount of activity, quality of the data and a host of other variables. This is why you need to be leery of estimates of bandwidth and storage calculation. Storage

calculators are kind of like the MPG stickers on a new car; no one ever seems to get that mileage, even going downhill in neutral with a tailwind.

The bitrates below are a general average for “acceptable” quality video on a 4CIF image but actual could be significantly higher:

| | |
|-------|------------|
| MJPEG | 5 – 10Mbps |
| MPEG2 | 3 – 5Mbps |
| MPEG4 | 2 – 4Mbps |
| H.264 | 1 – 2Mbps |

Again, a word of caution, the above bitrates DO NOT guarantee quality. In terms of storage, a good rule of thumb is at 30 frames per second (real-time) you can equate Mbps to Gigabits per hour. If you were using the above chart an H.264 stream at 30 frames per second (4CIF) would roughly require 1 – 2 GB per hour for very high quality video, while MJPEG might require as much as 10GB per hour. Again, this is very general and actual results will vary drastically. It is safe to theorize MJPEG at low bitrates will not produce a quality image. For more accurate information you can use a storage calculator at the Aventura Technologies website located at: www.aventuratechnologies.com

Exposing Poor Video Quality

When evaluating video quality you should view recorded video data with significant motion; which will expose any weakness in the compression scheme. Codecs may perform well if there is minimal

motion, as not much is being asked of the codec and processors.

A further recommendation would be if it's a DVR (As opposed to an IP camera) to record the maximum number of si-

multaneous channels, which may show any bottlenecking or resource sharing problem. Also, look to see what happens when you view the recorded video at full screen. Many times demonstrations are

performed and you are shown a small little video window. For surveillance purposes if you are trying to identify objects or subjects for evidentially purposes they are of limited value.

Quality of the Coding

We have not discussed the quality of the coding. Just because someone embarks on using a higher resolution, higher bitrate and H.264 will guarantee the perfect image. Image coding is a complex and highly specialized science. It is no different than cooking in some regards. We can all start with the best of intentions and the best ingredients used in the finest restaurants. All this means is you have the potential to make



the finest dish possible. But then there are Michelin chefs and some people who could burn water. Video coding is not add water and stir. There is no magic pill.



It takes time, years of research and development, talent and a lot of trial and error. So when someone announces they now have H.264 it could be years before

they have it right, if ever. Accordingly, an immature H.264 solution may look worse than a mature older codec.

Codec Profiles

Further to note, within the newer codecs like H.264 there are multiple "profiles." A profile for a codec is a set of features identified to meet certain sets of specifications of intended applications. There are over a dozen profiles within the H.264 codec family, so obviously some are better choices than others for video surveillance. While the H.264AVC initial set of profiles was

adopted back in 2003, the latest update came with the approval of the H.264SVC (Scalable Video Coding) standard in November 2007, which provides some unique efficiency for CCTV applications.

Codecs typically have been a decade or more in the making by standards committees before users begin to work on their individual flavor. Codecs are incred-

ibly sophisticated and as such are created by consortiums (Motion Picture Experts Group and International Telecommunications Union) of the most prominent companies in the world, from the Microsoft's to Intel's. So when someone says they have the ultimate proprietary codec, they developed, think twice. Most likely it is just a "flavor" of something already in existence.

To clarify one potential misconception H.264 is also referred to as MPEG4 Part 10 by the Motion Picture Experts Group, which is part of the new advanced codec standards. This should not be confused with MPEG 4 Part 2, which most people associate with MPEG4, which is the older generation codec using the Huffman Algorithm.

Hardware Factor in Processing Video

The final aspect of determining the video quality is the hardware by which it all comes together. Some codecs are clearly more efficient than others and so can be said for the hardware components. It is

the hardware that actually performs the work of processing the information. You can begin with best of breed all along the route to the ultimate in video experience but you are only as good as your weakest link. Com-

pression requires horsepower; horsepower is processing. The more advanced the compression scheme the more processing power required. Similarly, the higher the quality of the images, the larger the

file size, the more data involved and subsequently more processing power needed. A lack of processing power in a variety of areas will cause bottlenecks and degradation in quality.

There are two methods by which to compress the audio and video data – hardware or software. Hardware compression tends to be the best solution if the hardware is sized correctly as it can:

- Have an exponentially faster data rate throughput
- Can offload the compression task freeing up valuable CPU bandwidth
- Reduce power consumption

Software compression instructs the PC's processor for encoding the video, whereas hardware compression uses dedicated components and processing.

Conclusion

So when someone asks you how do you determine video quality (other than the naked eye)? The answer is: **Bitrate + resolution + codec + data quality + hardware = video quality**

Any shortfall in any area of the above equation may result in an inferior result.

One challenge you are going to encounter in your quest for determining video quality is manufacturers rarely provide you with adequate information to formulate even the most basic an-

swers. Even if a manufacturer is forthcoming with specifications on a datasheet be careful to note under what conditions you can expect that performance, remember the MPG sticker. It's not what they do tell you but what may be omitted.

Ultimately, unless you have scopes and a labo-

ratory, you have to rely on visual observation.

Video compression technology is a continuously evolving science. Advancements tend to be incremental as opposed to exponential. Whether it's the ordinary scheme or the hardware that processes the information, it is an evo-

lutionary process. It has taken two decades from the lunch pail cellphone to a touch screen Blackberry.

Good luck in your quest and always remember "caveat emptor", let the buyer beware.