Is It Really Sharp?

Resolution and sharpness—two different entities often confused with each other

■ By C.R. Caillouet

Any time a new video camera is announced, a lot of discussion goes on concerning the number of pixels on the camera's image sensor. Then some folks complain that the camera isn't sharp enough, while others deplore the harshness of the "video look" and proceed to apply softening tools in front of or behind the lens.

So what's the big deal about resolution and sharpness? Do you really need 1920 x 1080 to have HD? Is 1080i sharper than 720p? Is there really an advantage to 1080p? Can you use SD glass on an HD camcorder? Is my sharpness problem in the camera or the recorder? Does the answer in television always have to be "It depends"?

Well, the answer to the last question is an unqualified "Yes!"

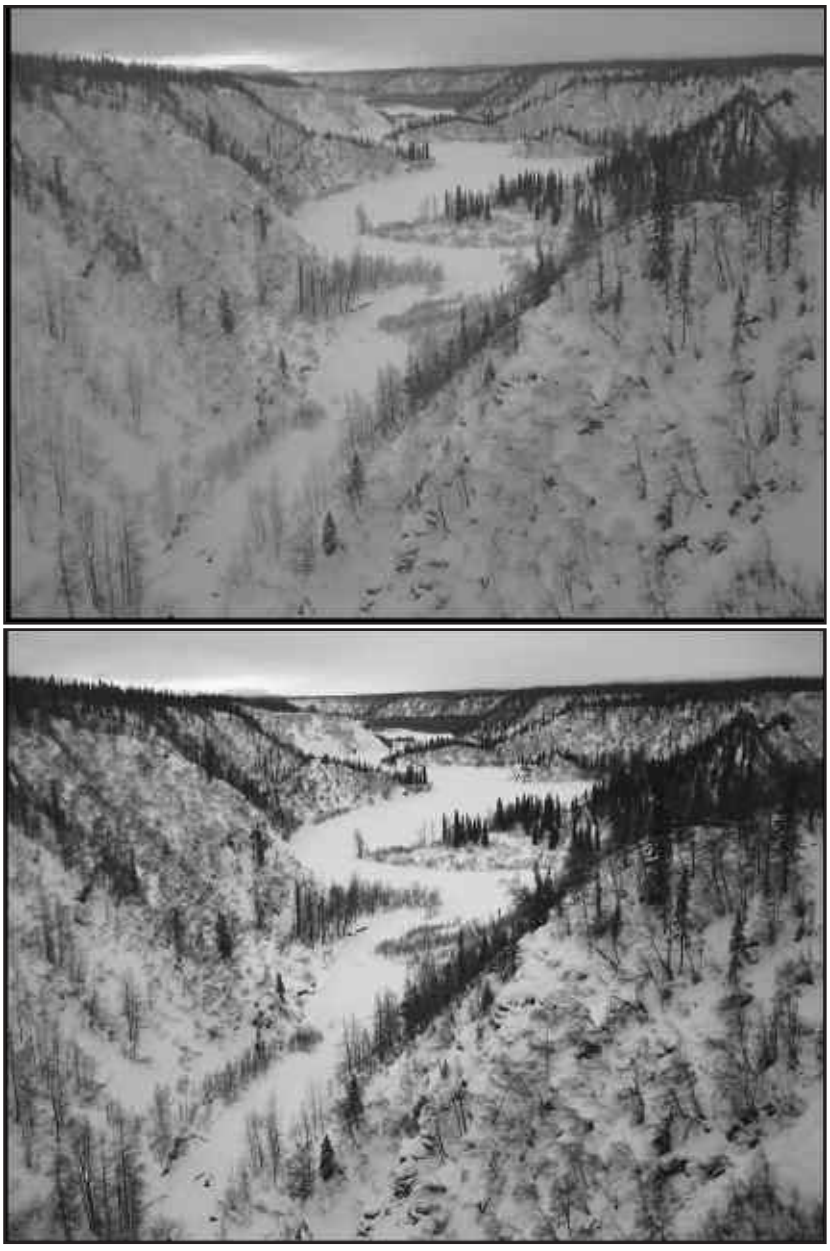
The other answers depend on what your criteria and assumptions are, what your display size is, how far away your audience will sit, and what nasty operations will get performed on your pictures before they get viewed.

Before I get too far along, I have to warn you that there isn't enough space in this column to completely answer all these questions, so I'll have to revisit some of them in later issues.

Resolution is a measure of the level of detail in an image. It's definable and measurable, although different groups might place the threshold of the detail at different points.

Usually, adjacent white and black lines are passed through the system in question, and the difference in contrast between the white and black is measured in the original scene and then at somewhere between the capture device and the display. We might call limiting resolution the value at which we can distinguish the finest white and black lines.

Limiting resolution is useful for specifying something about the system, but it might not tell us much about the sharpness of the images produced by that system.



These two grayscale images are identical, except for contrast adjustments. Which one looks "sharper"? Sharpness is a measure of the contrast of detail.

You see, the human visual system is much more sensitive to contrast

(Cont'd on page 94)

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MISINFORMATION

(Cont'd from page 21)

variations at some value near one-tenth of the resolving limits of our eyes. And contrast is the key to our perception of images as sharp.

So, to characterize an imaging system's sharpness, we must measure the contrast at several resolution points below the finest detail, then plot those results as a curve.

The result is called a modulation transfer function (MTF), and the area under the MTF curve represents sharpness. We can increase the area under the curve by pushing the limit out farther, or by boosting the contrast of the details lower in the resolution range. Often the latter approach is more cost-effective.

The sharpness phenomenon has been well understood in film technology for many years and probably explains why movies maintain much of their flavor after being reduced to small video screens. It's not all about resolution.

Another important point about MTF and imaging systems is that each optical or electronic element in the image path has an MTF associated with it, and those functions must be multiplied together to create a total system MTF.

Because most of those functions will represent a loss of detail somewhere in the curve, more elements in the system usually lead to softer images. To try to reduce the softening effect, designers often attempt to build "sharpening elements" into an imaging system.

Some sharpening elements are custom-tailored to offset specific effects of optical or sampling components. Others are generic tools to make the image appear sharper under normal viewing conditions, but do little to replace the lost resolution under the MTF curve.

Conventional image-enhancement circuits in television cameras often create nasty additions to an image by artificially amplifying edges or mixing edges from one image component into another.

One misconception about pixels and video is that you can get as much resolution out of a system as you have pixels available. (I'll assume that you know that we measure video resolution in TV lines, that each TV line corresponds to a black or white line, that it takes two TV lines to make a cycle per picture height, and that we convert horizontal resolution by the aspect ratio to make horizontal and vertical resolution comparable.)

The imaging format does set the maximum limits for the imaging system, and the resolution is limited by the number of capture sites on the image sensor.

However, let's stop there for a minute and think about a 1920 x 1080 pixel sensor imaging a scene with very fine detail, i.e., black and white lines. If the lines are just as fine as the spacing of the sensor pixels, you could capture two extremes—if the lines are aligned with pixels, you could get a black pixel next to a white pixel (forget about the reality of the optics for now); but if the pixels split the lines, you could get all gray pixels, with each pixel seeing half black and half white. And, of course, you could get anything in between.

So the maximum resolution that you could get from a sensor might be the same as the number of pixels, but the practical limit is somewhat lower because you're limited by the probability that pixels and details won't align.

The practical effect of trying to capture too much detail is the creation of false image content as the alignment of pixels and detail changes. We call this false content an alias. It might look like a jagged edge or a disappearance of detail in a patterned area. In either case, it isn't a true representation of the scene.

To avoid aliasing, the system must be limited to a resolution of somewhat less than the format limits, but how much is a design decision.

Some manufacturers use the alias components to make an image look "sharper," because even though the alias components are false, they do add content in the area below the MTF curve. Just don't look too close or try to use that detail for analysis or processing.

And a system with fewer alias components is more likely to attract the eyes of those folks who like "smooth" images, a "film look" or other descriptions that are hard for engineers to get their arms around.

I hereby resolve to resolve more resolution misconceptions in future issues (Sorry, but I couldn't resist.) HDVP