Pixels Ain't Square, Dude

Not all pixels are created equal. The shape (proportion) all depends on the format you choose to use. ▪ By C.R. Caillouet

We've talked about digital video quality and several of the decisions that can affect that quality, but what effects do those decisions have on the way that we handle the resulting video? One effect is a change to the shape of the sampling structure, distorting the shape of each pixel. If that effect isn't taken into consideration by devices after the recording, the image shape can be incorrectly reproduced.

Nonsquare pixel sampling started long before digital video compression—way back in the twentieth century. To understand the issues, let's start with a definition.

A "pixel" represents the area of an image in which the scene brightness is averaged and then assigned a number corresponding to the brightness in the "sampled" area. Unless the area sampled has a similar width and height, the sample will represent a nonsquare area with each sample wider or narrower than it is tall. The sampling rate determines the shape of each sample.

There's nothing new about asymmetrical sampling. Video system designers have been dealing with odd sample shapes for years because of the way that early video systems evolved from analog to digital processing. The first digital video systems sampled composite (NTSC or PAL) video at four times the color subcarrier rate.

The color subcarrier is the signal embedded in holes in the video brightness signal in order to carry color information without affecting the ability of older black-and-white equipment to see only brightness. Choosing four times the color subcarrier as the sample rate had the useful effect of making digital encoding and decoding much simpler, because each process required only addition and subtraction operations at a time when digital processing was much slower

"If a display system handles pixel aspect ratio properly, these representations should all display with the same shape as the top one. Each format is shown displayed by a system that always expects square pixels. The white box in each one shows the original area sampled to make fewer pixels cover the same image width.

and less sophisticated than it is now.

That long-winded paragraph was necessary to explain why early digital video systems used pixels that were actually narrower than they were tall. Four-times-subcarrier sampling (768 samples per NTSC video line) was higher than that necessary to retain the brightness or "luma" resolution because the color or "chroma" information had to be extracted from the same signal. The chroma didn't need as much resolution as the luma because the human visual system can't resolve color at as high a detail as luma, but it did require more information than the luma alone. The result was a pixel shape about 0.8 times as wide as it was tall.

As digital processing improved, digital video sampling changed from 768 to 720 samples per NTSC video line (pixels 0.9 times as wide as tall) to accommodate a global sampling rate that would allow equipment to deal with NTSC and PAL signals based on a common clock. The 720 x 480 format was standardized by the international community and is embodied today in the ITU-R Rec. BT.601-5 image format used in DV, DigiBeta, D-1 and D-5 videotape.

Even with pressure from the computer-software community, the concept of asymmetrical pixels stayed with

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video until the Society of Motion Picture and Television Engineers (SMPTE) standardized digital high-definition television in SMPTE 274M. SMPTE 274M gave us the now-familiar 1920 x 1080, 16x9 aspect-ratio images, with "square" sampling.

The infamous ATSC A/53 Table A-3, describing four different sampling structures for digital television (DTV) systems, although not officially accepted by the FCC, created a de facto standard, including the square sampled 1920 x 1080, 1280 x 720 and 640 x 480, plus the legacy non-square sampled 720 x 480.

When we start playing around with resolution reduction as a way of reducing the data load prior to recording, we can end up with images containing lower resolution in the horizontal direction. If we don't change the sampling structure of the image, we can still get an improvement in data rate after digital compression because less information is conveyed about the high frequencies in the image. But most portable systems don't wait for the compression stage to drop information; they drop it up front by sampling fewer times across each video line. Dealing with fewer samples from the beginning of the digitization process lightens the processing load on all the camera circuits, reducing speed, memory, size and power requirements.

But reducing the number of samples per line not only gives the image asymmetrical resolution numbers (as in the case of the 720 x 480 format described above), it also changes the shape of each pixel.

The two most familiar cases of horizontal "sub-sampling" are contained in the specs for the two most popular portable HDTV formats. Sony's HDCAM record format reduces 1920 x 1080 images to 1440 x 1080 for recording, and Panasonic's DVCPRO HD format reduces 1280 x 720 images to 960 x 720. The early versions of HDV cameras used similar techniques to minimize record loads, but as processing power increases and new, more efficient compression algorithms appear, the need for sub-sampling before compression is becoming less important.

Next month, we'll discuss the implications of nonsquare sampling on processes occurring after the clip leaves