Characterizing the Gain and Read Noise of a Lumenera SKYnyx 2-0m Videocamera

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February, 2011

Abstract

This describes the measurement of gain and read noise in a Lumenera SKYnyx 2-0m digital USB video camera. Although typical CCD's can be characterized with a few flat field and bias frames, video cameras have complications caused by variable gain and shifted output of the bit fields. This study attempts to elucidate these complications and give insight into the role of gain settings in the camera performance.

Method

I used LucamRecorder to capture video from a SKYnyx 2-0m video camera. LucamRecorder allows control of frame rate, exposure, gain, gamma, and more – which provides a large parameter space to explore. In addition, it allows 8 or 16-bit video output. The camera is inherently 12-bit, so the means by which it converts to 8- or 16-bit output needs to be established.

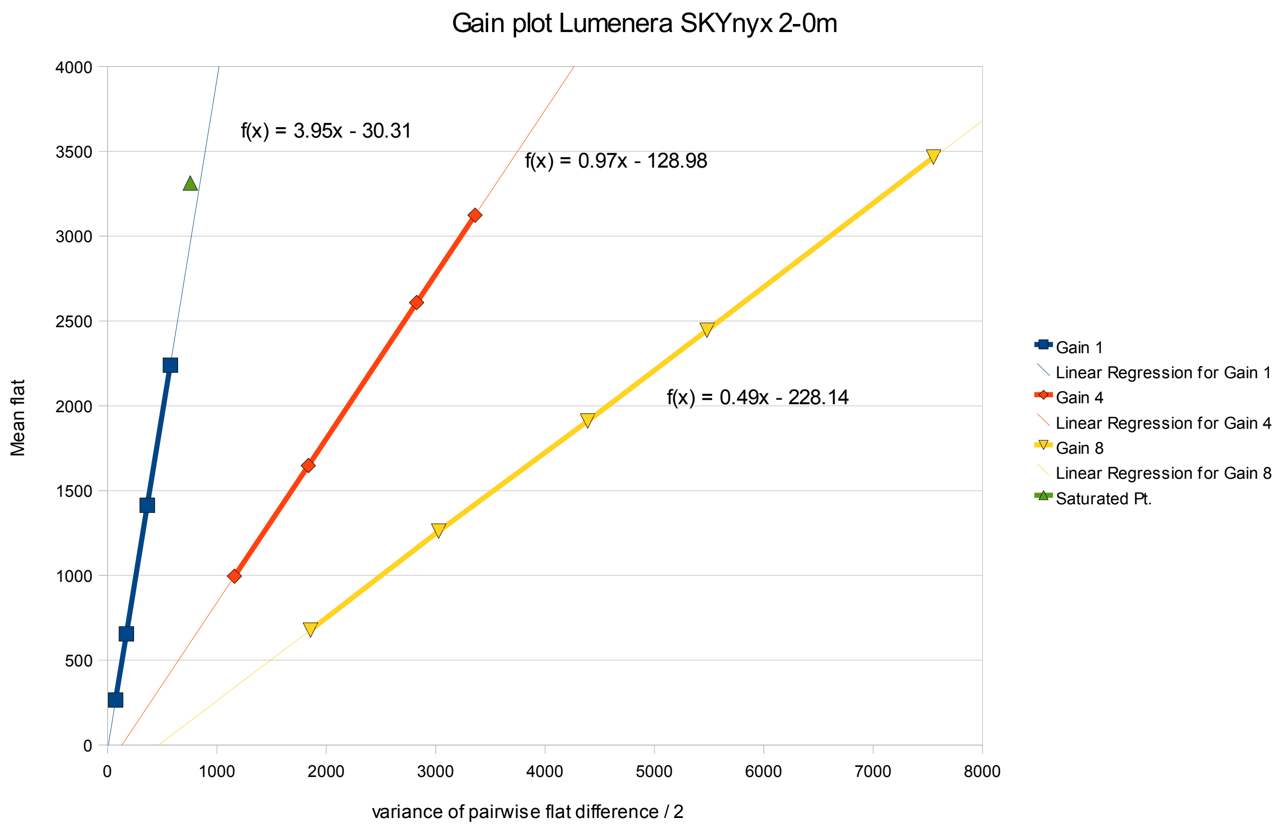
Normally video is output as 8-bit AVI and there are few applications that can deal with some form of 16-bit AVI codec. For this reason LucamRecorder outputs a special format, .SER, that allows either 8- or 16-bit output. After some experimentation I determined that the 8-bit output (either .ser or .avi) corresponds to the *high* 8-bits of the 12-bit camera output. This means each ADU in an 8-bit video corresponds to 16 ADU in the detector itself. Furthermore, the 16-bit .ser format corresponds to the 12-bit format shifted left 4-bits so that its high end is closer to the full 16-bit range of 65535. This means that in 16-bit mode, each ADU corresponds to 1/16 ADU of the 12-bit camera output. In practice, the 8-bit output should be shifted left 4-bits to restore the true scale of the CCD, and the 16-bit output should be shifted right 4-bits.

The SKYnyx 2-0m camera uses a 1/3” Sony ICX424 CCD. Lumenera states that its read noise is 10 e- RMS, and its dark current is less than 1 e-/s. The CCD has settable gain, but I could not find documentation on the actual values of realized gain as a function of GainValueSetting, which ranges from about 1 to 20.

To simplify the characterization process I set the camera to 33 fps with 30 ms exposure and I only adjusted the gain on the camera for various values of applied flat field illumination. This allowed a study of variance in the flat field illumination as a function of mean illumination, which then allows a fit to the actual gain under the assumption of Poisson statistics. I wrote custom code to analyze the 16-bit .ser files.

Normally one measures gain in a CCD with Flat frames and bias frames, but for these short exposures and very low dark current of < 1e-/s a video dark frame is equivalent to a bias frame. Thus I only took a single set of dark video frames at each gain setting – to serve as bias frames for each corresponding flat field video frame.

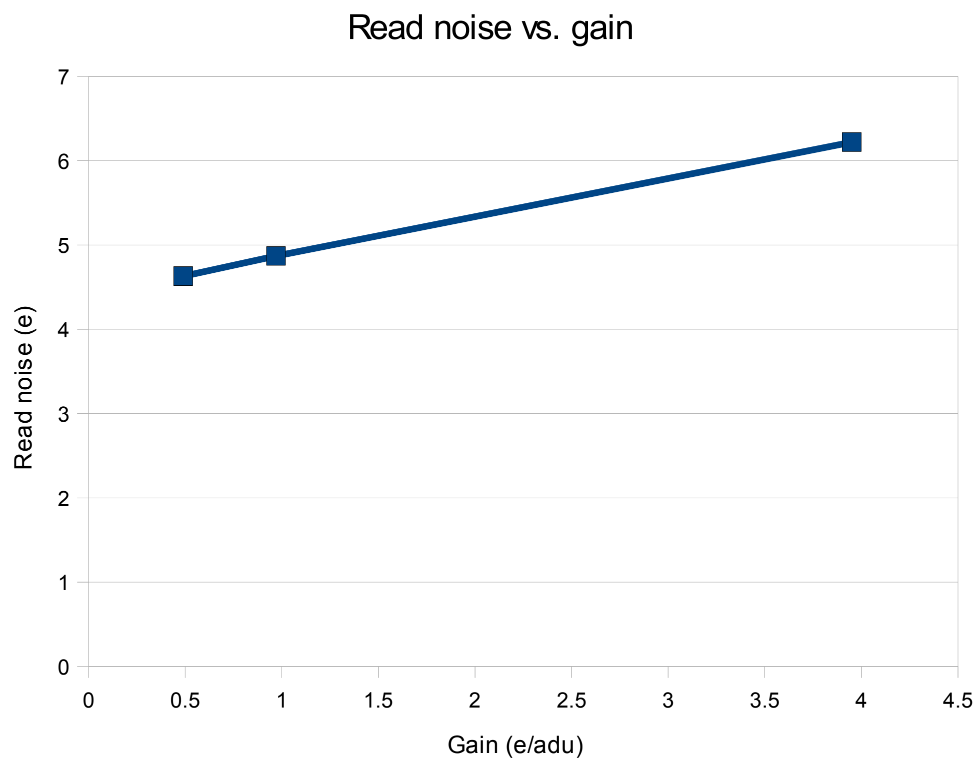
The result is shown in the following figure:



Each line corresponds to a series of flat field videos captured at a given gain setting and for a number of different flat field illumination intensities. This plot shows the mean flat field, in ADU, vs. one-half the variance of the pairwise frame difference. Shown this way, the slope of each line corresponds to the gain of the CCD at that particular gain setting, with steeper slope corresponding to a higher gain value (e- per ADU) and therefore a lower sensitivity.

The gain curves show good linearity for all points except the single triangle in the upper left, which corresponds to nearly saturating the ccd at the lowest gain setting of 1.0.

Knowing the gain values from the slope I then calculated the read noise for each gain setting based on the variance of the pairwise subtracted “dark” or “bias” video frames. The read noise dependence on gain appears in the next figure:



Here we see that there is a linear dependence of read noise on gain, with a clear reduction in read noise (in e-) when the gain is increased to make the camera more sensitive. The read noise is approximately 5-6 e-, which is below the stated value for the camera.

Now we can see the effect of gain setting on the true gain and read noise of the video for both 8- and 16-bit output:

gainsetting	actualgain	3.95/gainsetting	Read noise e	8 bit gain	8 bit read noise ADU
1	3.95	3.95	6.22	63.2	0.1
4	0.97	0.99	4.87	15.52	0.31
8	0.49	0.49	4.63	7.84	0.59

The actual gain is given very accurately by the formula, 4/GainSetting (3.95 to be exact). For 8-bit output this needs to be multiplied by 16 since the ADU's are “bigger” - which makes the read noise much less than one ADU in 8-bit video mode. In order not to lose faint information in 8-bit mode, it may be beneficial to use high gain and/or gamma. In 16-bit mode the output must be shifted right 4-bits to recover the inherent CCD pixel values.

In terms of full well capacity, the one point that shows saturation in the gain plots above corresponds to 13,000 electrons. The linear point below it is at 8,800 electrons – placing the high end of linearity at roughly 10,000 electrons. This means that the full output range is very linear except when the gain setting is 1.0, for which the top end becomes slightly nonlinear.