binning

Binning is the combination of two or more CCD image sensor pixels to form a new "super-pixel" prior to readout and digitizing. As a result, the generated charge carriers accumulate from the single pixels. This improves signal-to-noise-ratio (SNR), allowing exceptional quality image recording, at extremely low light levels. It also results in a reduction in the image spatial resolution.
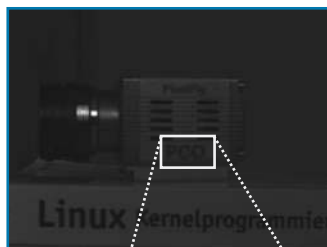
no binning
=> 640x480 pixels
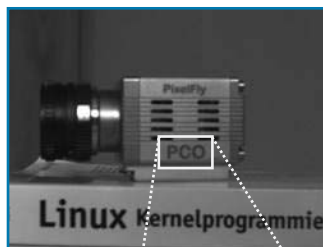
2x2 binning
=> 320x240 pixels

4x4 binning
=> 160x120 pixels

The no binning image illustrates a resolution of 640x480 pixels (VGA). While the 2x2 binning image uses the same exposure settings as the no binning photo, the two binned pixels in the x- and y-direction achieve a resolution of 320x240 pixels. The 4x4 binning photo illustrates the highest amount of brightness at 4x4 binning, where 16 pixels have formed the new super-pixels with a resolution of 160x120 pixels for the total image.

no binning

2x2 binning
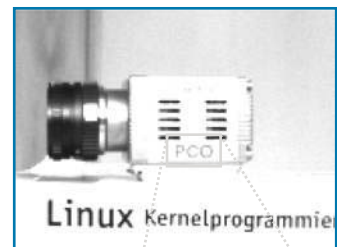
4x4 binning

The same series of images (above) with increased binning from left to the right have been magnified to show the loss in spatial resolution. The magnifications illustrating the letters "PCO" were further processed for greater brightness and contrast to accentuate the loss of spatial resolution by binning.

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binning

advantages

- improved signal-to-noise-ratio (SNR) as the readout noise contributes only to a readout pixel, and does not accumulate if the charge carriers are combined. Combining pixels via image processing does not improve the signal-to-noise ratio.
- higher image repetition rate (image recording frequency) because of lower spatial resolution.

disadvantages

- reduces the spatial resolution by the combined number of pixels
- reduces the detectable amount of light per pixel (pixel dynamic), only if a certain maximum amount of charge carriers (full well capacity) of a pixel generates a maximum number of counts. This maximum amount of charge carriers are proportional to the number of combined pixels, therefore attaining the maximum number of counts at lower light levels.
- when the combination of pixels are not symmetrical, unequal numbers of pixels in the x and y direction are combined, resulting in distortion that requires image processing to correct.

additional information

In the majority of existing CCD image sensors, the serial shift and summation point register before the Analog-to-Digital conversion have enough capacity to accumulate charge carriers that are twice as large, compared to the full-well capacities of each pixel.

Binning is primarily used for low light level applications, and configured CCD image sensors, where the readout noise (mainly in cooled CCD image sensors) is dominant, since other noise contributions such as dark current accumulate with binning.