

# Getting the Light Out

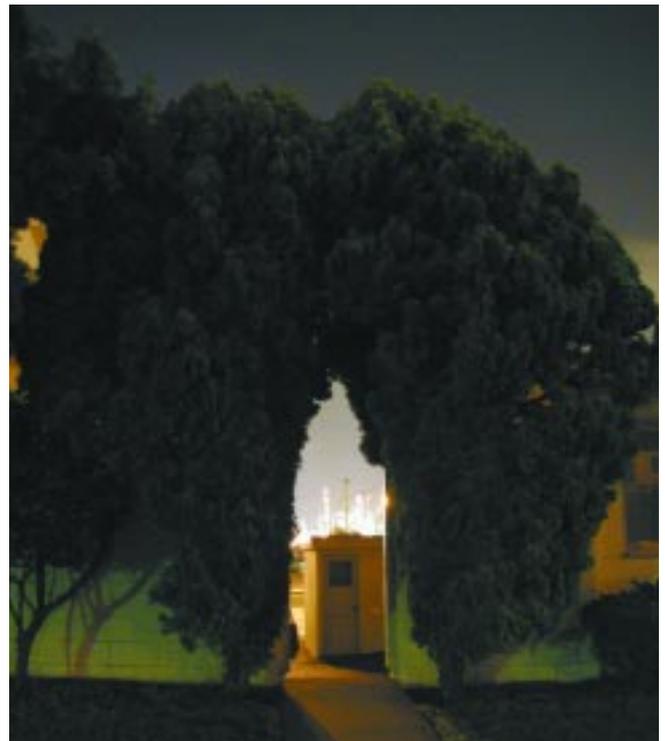
Eliminating Dark Current Noise in Long-Exposure Digital Images

By John Heidemann

One of the best things about digital photography is the instant feedback. Snap a picture and you've got a 1x2-inch preview of the image you just took, and minutes later you can view that image on a monitor or make a print. Compare this turnaround to the hours or days required to get prints or slides from film. This rapid feedback is terrific for learning how to take great pictures in unusual

conditions. For instance, infrared and night photography each require some practice.

The downside to night photography with digital cameras is *dark current noise*. In addition to higher grain, long exposures turn certain CCD elements on, giving your picture of the night sky a few extra stars! Fortunately, with a little care, this problem can be greatly reduced. Below you see the original noisy image on the left and



Left: The original image (16 second manual exposure, f/2.8, 100 ISO equivalent) shows dark current noise. Right: the final image after adjustment.

the same image after correction on the right.

Dark current noise is a kind of noise in long-exposure images taken on CCDs. Camera imagers consist of an array of CCD elements. Normally these elements are triggered by light entering the camera, but they can also be triggered spontaneously by stray electrons. Since electrons from noise are as good as electrons generated from light, this noise shows up as bright pixels in the image where they shouldn't be.

How much of this spontaneous current occurs depends on the exposure duration (longer exposures get more noise) and the camera temperature. At room temperature, today's digital cameras begin to exhibit noticeable dark current noise for exposures longer than a few seconds.

Astronomers typically avoid dark current noise by cooling the CCD. The noise is typically halved for every 5 degree Celsius drop in temperature, so cooling it to -30 to -40 degrees Celsius (-20 to -40 degrees Fahrenheit) avoids much of the problem. Unfortunately, few photographers carry around liquid nitrogen, and fewer still would want to apply it to their cameras (something the camera makers probably appreciate!). Fortunately, we can remove most dark current noise by post-processing the image.

### Averaging Away the Problem

The simplest way to eliminate noise is to blur the image slightly.



Noisy pixels are eliminated in this image, blurred with Radius=1.5, but the high-contrast edges are also lost.

Since noisy pixels are randomly distributed around the image, rather than clustered together, Filter>Blur>Gaussian Blur will quickly blend them into the background. Blurring will also reduce the grain in the image, not a bad thing for long-exposure, high-grain images.

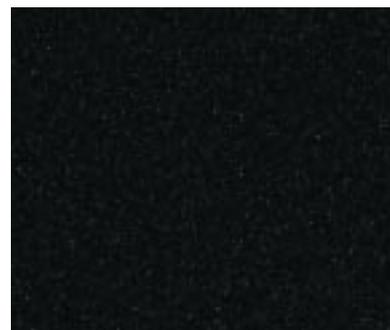
Of course, the downside of

blurring is that it gets rid of the high-contrast edges in the image in addition to the noise. For example, the details in the refinery lights are gone. You can partially correct for this by sharpening the image (Filter>Sharpen>Unsharp Mask), but we'd really like to change just the noise, not the whole image.

### What's the Difference?

Fortunately, the sensitivity of CCD elements to dark current noise is relatively stable. The same pixels that are noisy in one picture will be noisy in the next picture, if it's taken soon and at about the same temperature and conditions. Because of this level of stability, you can measure the noise and remove it.

To record what dark current noise is infecting your image, take another image (the "dark" image) immediately after taking your "light" image, using the same settings, but with the lens cap on. At the same temperature and exposure, this dark image will record which pixels are generating noise. We'll call this image the DCN correction.



A portion of an image taken soon after the original, under very similar conditions but with the lens cap on, reveals dark current noise.

WE UT IT LL  
T GETHE F Y U

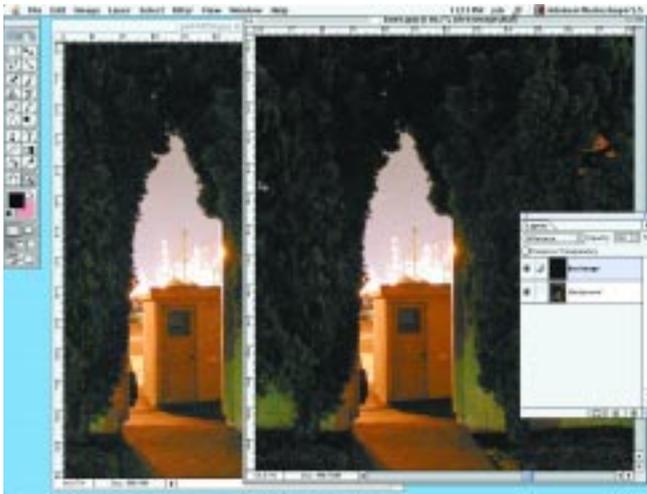
*The trust st n r f xc ll ne  
s e lzn nlr t l  
stu nst ll t ns.*

www.c ty- t l.c m  
/ 535.7  
LL S / H UST N / NEW Y K / S INT L UIS / S N F NCISC

More info? PEInfo No. 39

CCD elements fail by becoming oversaturated. A natural way to fix this is to simply subtract these pixels. Take the base image, hold down the shift key and drag the DCN correction image onto it to create a new layer, and select the Difference mode in the Layers palette. Now the noise in the dark sky and trees is gone.

But there's a downside to differencing. Subtracting the noise works well for astronomers looking at stars at night. Unfortunately for photographers, subtraction creates the opposite problem of lit-up pixels: dark spots now show up in bright parts of the image (look at the refinery lights). Dark current noise occurred even in these bright areas of the image. Although we don't want noise in the dark areas of the picture, we need to keep it in the bright parts!



Paste the dark image over the original image and select Difference in the Layers palette to eliminate noise in the dark areas.

## Adding Things Up

What we really want to do is not subtract off the noise, but to replace noisy pixels with the better ones.

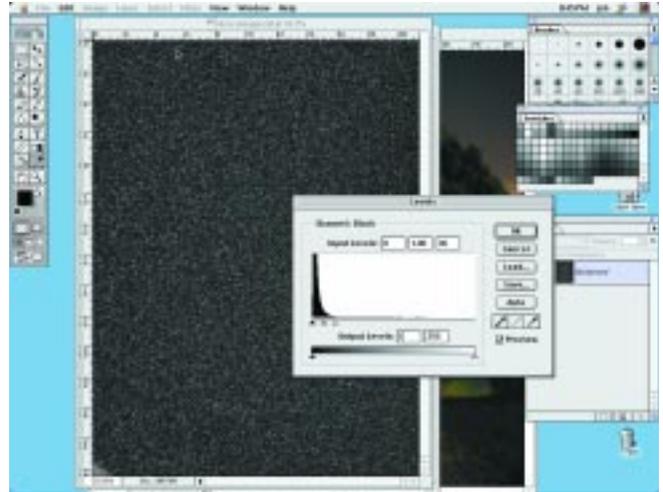


Use a very blurred image layer for your replacement pixels.

This leads to our final approach, combining these two methods. We use blurring to generate good data for the replacement pixels, and the noise-only image to control which pixels to replace.

First we need to get good replacement pixels. Take the base image,

duplicate it into another layer, and heavily blur that layer. (The exact blur radius depends on image resolution, but don't be shy. I used Radius=5.0.) No more noise here. Name this layer "DCN replacement."



Turn up the gain in your DCN correction image to use it as a mask.

Now open the DCN correction image in another window. When you open it, *do not* allow any color management; the raw data is needed in the next steps. We'll use it to construct a mask to choose which pixels to replace. Convert it to grayscale (Image>Mode>Grayscale).

Typically only a few elements are completely blown, but many will be partly corrupted. We need to replace all the pixels, so turn up the gain (Image>Adjust>Levels; click "Auto"). Make sure the output levels are scaled 0 to 255 and that most of the image remains black. This image will serve as the mask for the DCN replacement layer, so select it all and copy it (this will be the "DCN mask"). Go back to the base image and select the "DCN replacement" layer in the Layers dialog, add a mask (Layer>Add Layer Mask>Reveal All). Then paste the DCN layer into the mask (opt/alt-click on the mask and paste it).

As a final step, you may wish to apply a light Gaussian blur (Radius=0.5 pixel) to the image, which will remove some of the remaining grain.

You're now set to take long-exposure pictures at night.

John Heidemann is a research assistant professor of computer science at the University of Southern California. Before joining USC, he developed image processing software at the University of Nebraska-Lincoln Remote Sensing Center.