Reindeer Graphics® Adaptive Equalization

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Adaptive Histogram Equalization

A Photoshop compatible plug-in from the publishers of

Fovea Pro and The Image Processing Tool Kit

This Photoshop-compatible plug-in enhances the visibility of subtle detail in images, while compressing the overall range of brightnesses. This is particularly useful when pictures have a wide dynamic range from bright to dark, with low-contrast features present in all portions. By increasing the local contrast and suppressing the gradual variations across the image, the appearance of the picture is improved on the computer screen and hardcopy printouts.

Technical background

The underlying reason for this technique is that human vision can only detect local brightness changes of about 2-3 percent, depending on the viewing conditions. A typical (8-bit) digitized image has 256 grey scale levels, and some cameras, scanners and other instruments produce images with much higher range (14 bits from a cooled astronomical camera corresponds to 16,384 grey scale levels). These cannot all be distinguished by the eye, and in fact cannot be displayed or recorded by most output devices (computer displays, printers, etc.) and at the high end even challenge photographic film.

Several approaches have been used to perform this type of image processing, some of them very ad-hoc and without any sound scientific or mathematical basis. The most generally accepted and successful are “unsharp masking” (a term borrowed from photographic darkroom technique) and “local histogram equalization”.

The first of these is a linear technique, meaning that it can be carried out using an array of weights that are multiplied by each pixel and its neighbors to produce a summed result that replaces the pixel. The optimum array of weights is a Gaussian filter, and Photoshop and many similar programs include this function (with the ability to add a proportion of the result to the original image). Logically, it is equivalent to making a copy of the image, blurring it enough to remove the desired small details, and then subtracting this image from the original to enhance the visibility of those details. In many cases it is more efficient to actually perform the operation using Fourier transforms, in which case the method may be described as a high pass filter (meaning that it preserves high frequencies). The details of how the unsharp masking method is implemented influence the speed of computation but not the results. One of the drawbacks of this method is that it is sensitive to noise, which is generally high frequency and is amplified in the process. A more elaborate method called the difference-of-Gaussians (D.O.G.) filter can be used to deal with the noise.

The second method mentioned above uses the histogram in a small region around each pixel in the image. The histogram is a graph of the number of pixels having each possible brightness level. Equalization, which is sometimes applied to an entire image, assigns new brightness values to each pixel based on the original brightness level, so that the cumulative histogram becomes a straight line. This means that all brightness levels are used for equal areas in the image. Local equalization applies this same logic to the histogram of each region but keeps the new brightness level only for the central pixel. The result is to make pixels that are slightly brighter (or darker) than their surroundings much brighter (or darker) thus increasing local contrast. For practical reasons of implementation, many systems use a moving square neighborhood (the Local Equalization routine in The Image Processing Tool Kit and Fovea Pro uses a circular region of adjustable size). This method also amplifies noise and does not show fine detail equally in different areas of an image that vary in average brightness.

The mathematics behind the Adaptive Histogram Equalization plug-in is described fully in a paper by J. A. Starck (1999) “Adaptive Image Contrast Enhancement using Generalizations of Histogram Equalization” in the IEEE Transactions on Image Processing. It combines the best features of unsharp masking and local equalization, and adds a few additional functions for display adjustment. Pixels in a symmetric neighborhood are used with Gaussian weighting to construct a histogram used for equalization, and the result can be added to an adjustable fraction of the original image. In addition, noise rejection and a non-linear expansion of contrast have been added.

Using the plug-in

The four parameters that the user can enter in the control dialog all have a range measured in percentage. They can be entered numerically or adjusted using the sliders, while the scrollable preview window shows the results.

• Neighborhood center weighting controls the the effective size of the local neighborhood. The range is from 0% (standard deviation = 15 pixels) to 100% (standard deviation = 3 pixels). Increasing the value emphasizes more local contrast (higher frequencies, smaller features).

• Nonlinear expansion of the contrast applies a “gamma” function to the local differences detected by the equalization. A value of 0% corresponds to a linear contrast scale while a value of 100% is quadratic. The “S-shaped” contrast function increases differences of pixels from middle grey.

• Noise rejection is accomplished by a "difference-of- Gaussians" method applied to the region weighting. Unlike Gaussian smoothing, this does not blur edges. 0% corresponds to no noise rejection and 100% to maximum noise rejection.

• A percentage of the original image can be add to the equalized result. A value of zero only shows the changes the plug-in would make, which is useful if you desire to use your own blending mode, while a value of 100% gives an equal weight to the equalized result and the original image. Usually a value of 75-150% of the original image produces the most pleasing result.

The Photoshop plug-in works on 8- and 16-bit grey scale images and 24- and 48-bit RGB images. Many Photoshop-compatible programs only handle 8 bit grey and 24 bit RGB images (a few handle only grey scale images), but can still use the plug-in for those image types that are supported. For color images, the program extracts and processes the luminance value, preserving the hue and saturation.

A few examples will illustrate the possibilities which this filter offers (Note - these images have been jpeg compressed after processing, to reduce the size of this document):

1. A forensic image of a fingerprint on a magazine cover. The underlying contrast of the printing obscures the fingerprint. After processing the ridge markings can be seen clearly on both the bright and dark regions.

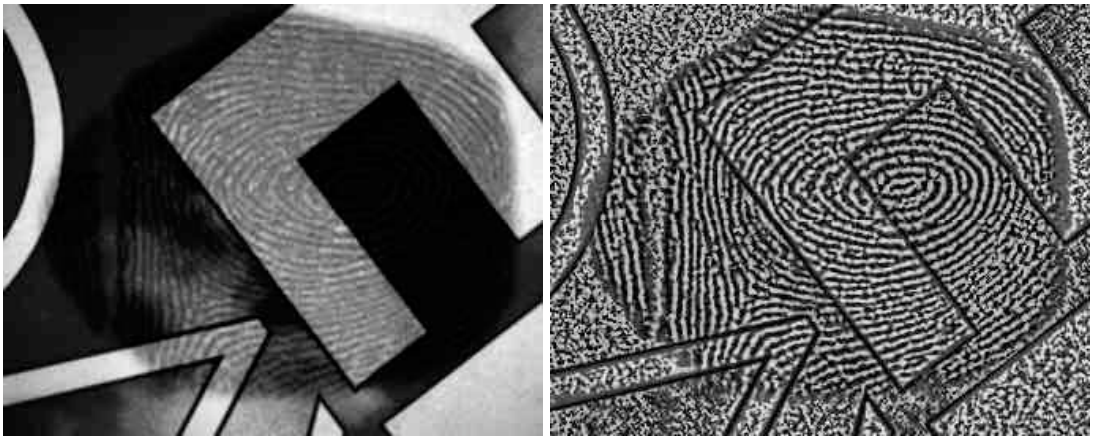
2. An SEM (Scanning Electron Microsope) image of dried paint. As is common in the SEM, the brightness varies with local slope and makes it difficult to see the fine detail in both the bright and dark regions. After processing the fine detail is enhanced, even in the dark recesses on the surface.

3. A scanned probe image of the surface of a coin. Grey scale values represent elevation in this image, and small scratches and bumps are obscured because of the large dynamic range of the data. After processing the scratches and fine details can be seen in both bright and dark (high and low) areas.

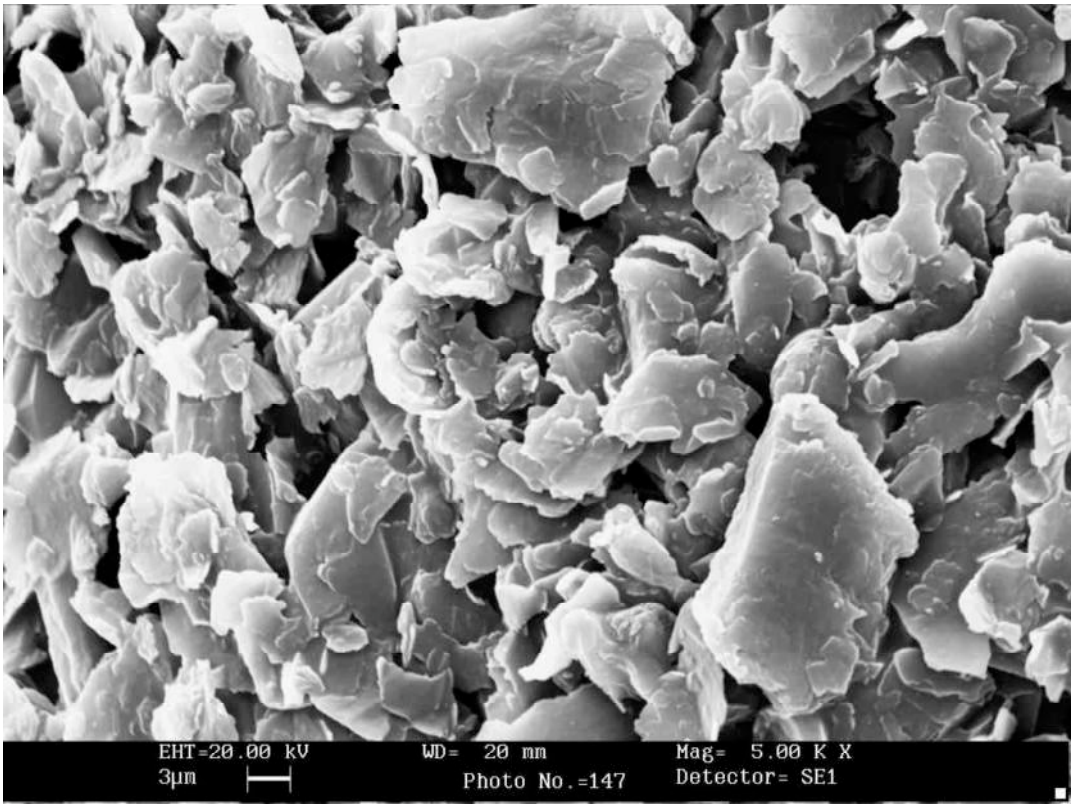
4. A color photograph with high contrast between brightly lit and dark interior regions. After processing, the details in shadow areas can be seen.

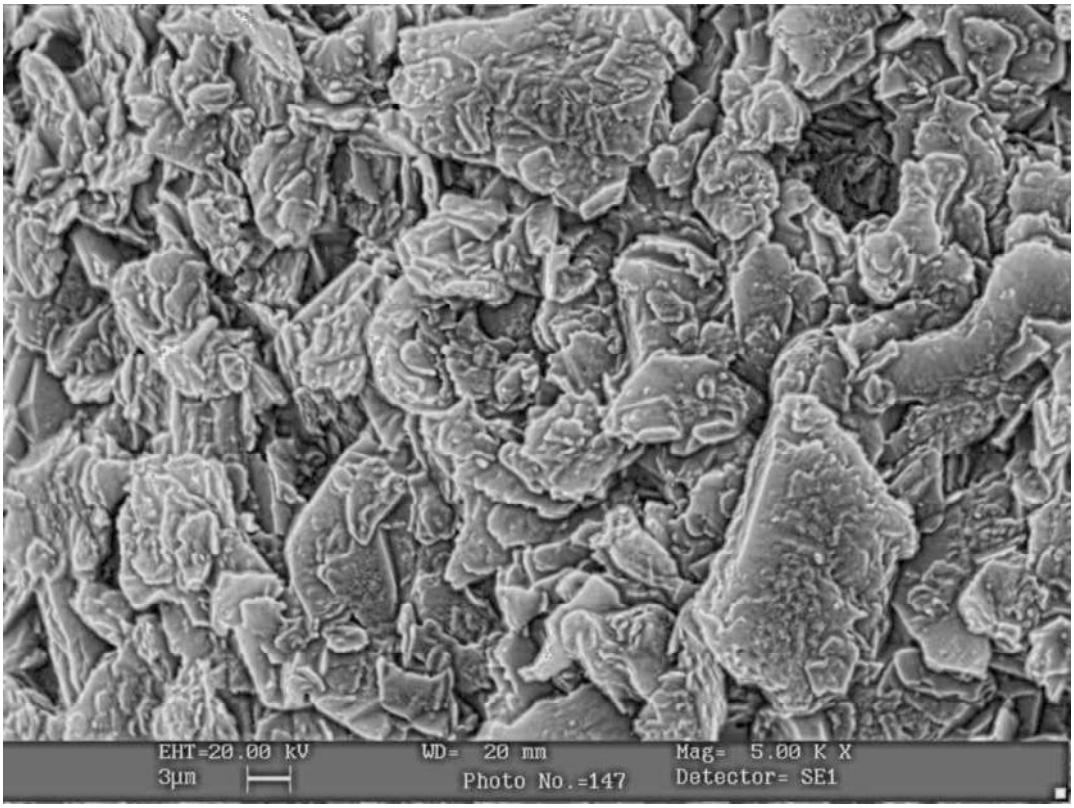
Important notice

Reindeer Graphics is distributing this plug-in as an example of the capabilities that such plug-ins can provide and to introduce users to the very powerful set of image processing and measurement functions in The Image Processing Tool Kit and Fovea Pro. The Tool Kit provides more than 150 plug-ins for image processing and measurement of 8 bit grey and 24 bit RGB images, plus a complete image analysis package with an extensive hands-on tutorial, for only $249.95. Fovea Pro adds support for 16 bit grey and 48 bit color images, plus additional functions such as stereo visualization and measurement and automation tools, including an expert system for feature classification, for only $799.95. Tool Kit users can trade up to Fovea Pro for a reduced price. Ordering information is provided on the web site.

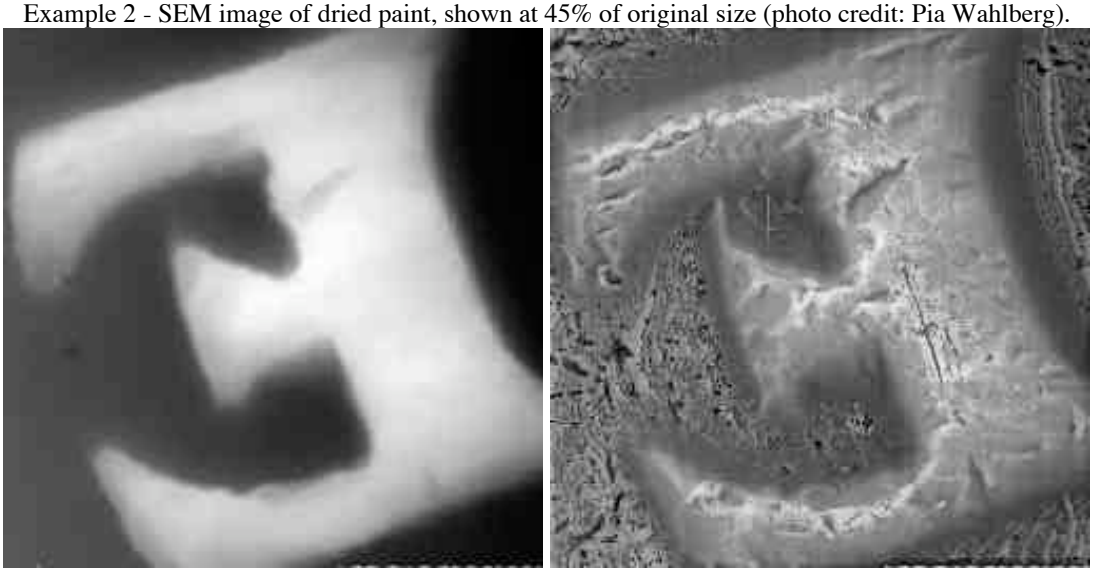


Example 1 - Fingerprint image before and after equalization, shown at 70% of original size.





Example 2 - SEM image of dried paint, shown at 45% of original size (photo credit: Pia Wahlberg).



Example 3 - Scanned probe image of coin surface, shown at 95% of original size.

Example 4 - Color photograph, shown at 65% of original size (photo credit: Eastman Kodak).