

Adaptive Histogram Equalization

**A Photoshop-compatible plug-in
from Reindeer Games, Inc.
publisher of**

Fovea Pro

(for 16 bit grey and 48 bit RGB images)

and

The Image Processing Tool Kit

(for 8 bit grey and 24 bit RGB images)

Adaptive Histogram Equalization Plug-in

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 from 0.0 to 1.0. They can be entered numerically or adjusted using the sliders, while the scrollable preview window shows the results.

- Neighborhood center weighting controls the effective size of the local neighborhood. The range is from zero (standard deviation = 15 pixels) to one (standard deviation = 3 pixels). Increasing the value from zero to one 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 zero corresponds to a linear contrast scale while a value of one 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. Zero corresponds to no noise rejection and one to maximum.
- A fraction of the original image can be added to the equalized result. A value of zero flattens the overall image contrast completely, while a value of one leaves the original image unchanged. Usually adding 20-60% 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

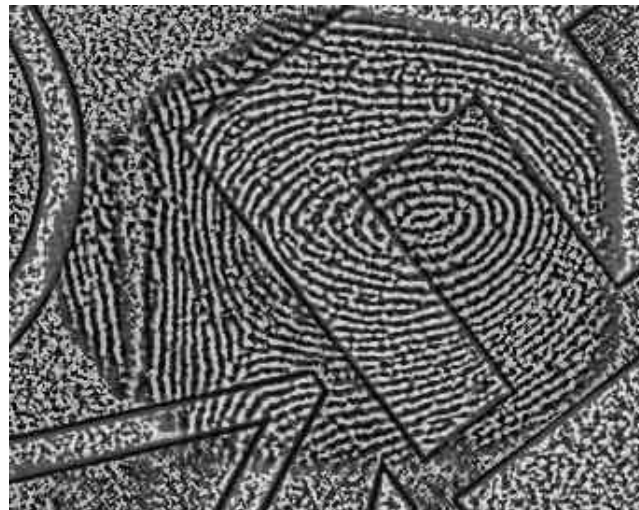
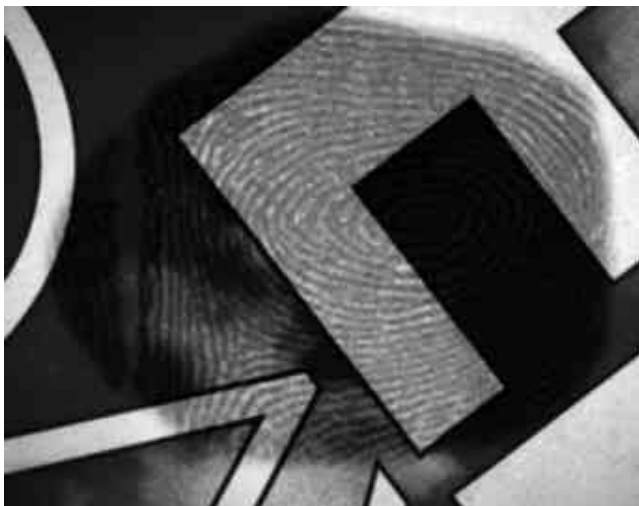
ridge markings can be seen clearly on both the bright and dark regions.

2. An SEM (Scanning Electron Microscope) 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.

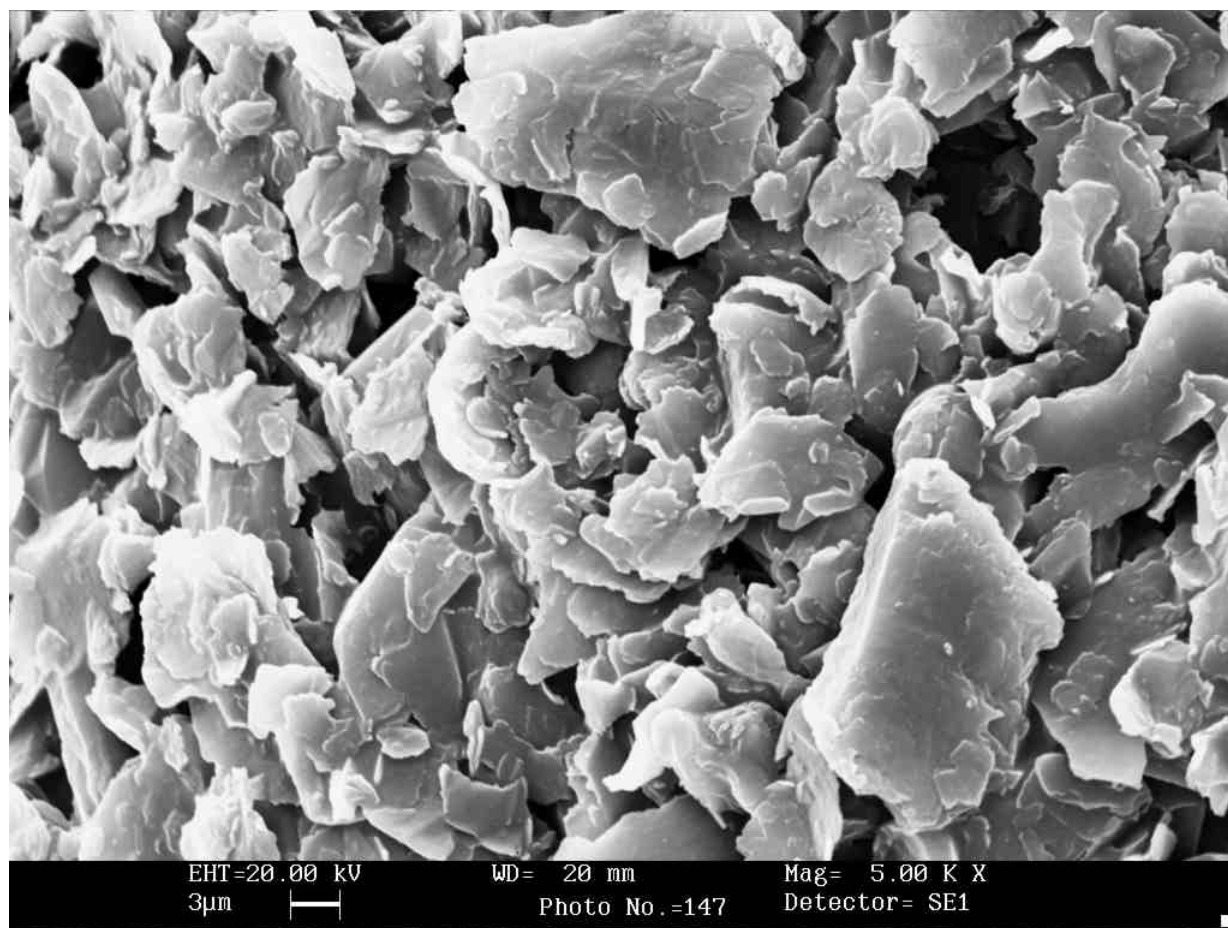
Important notice

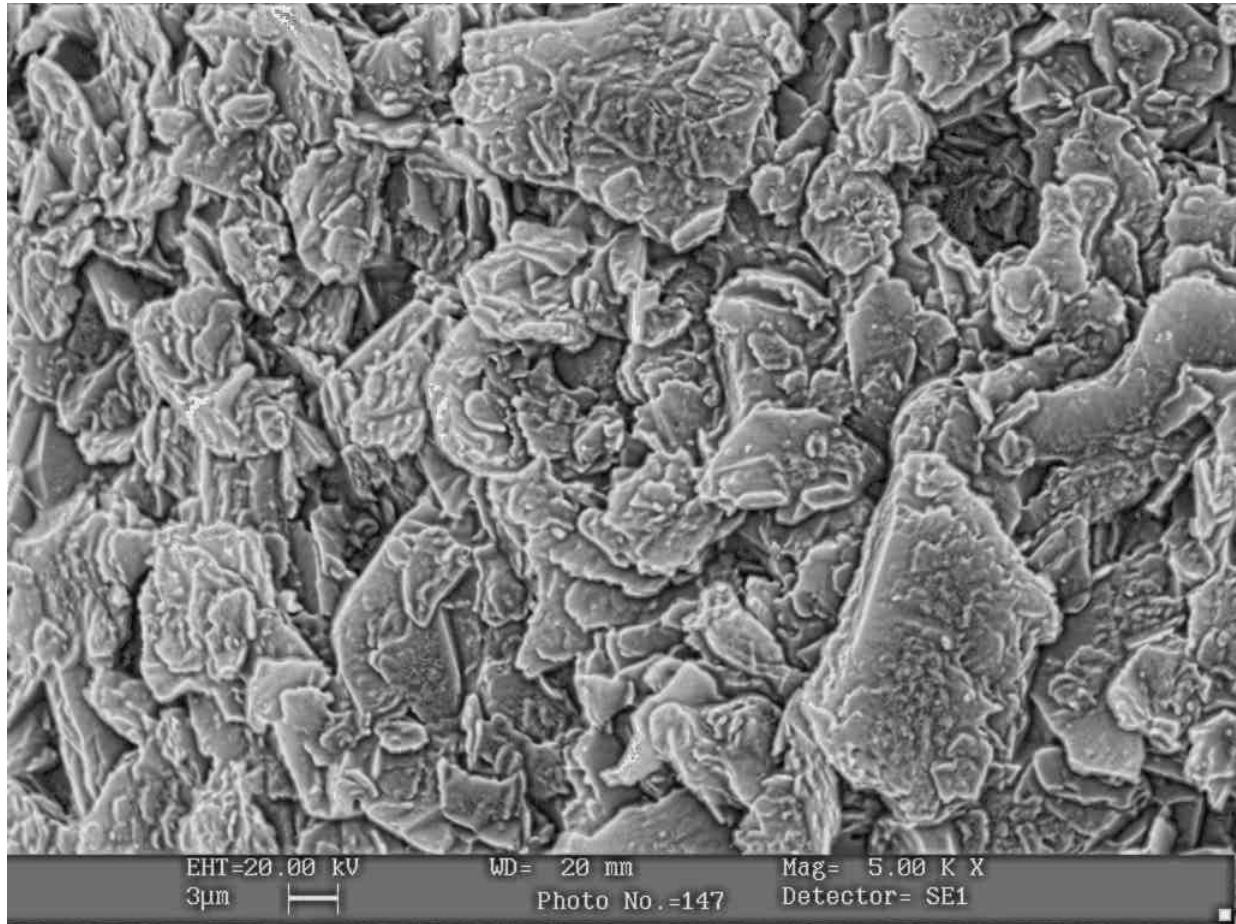
This filter is Copyright © 1999 by Reindeer Games, Inc. All rights reserved. Versions for Macintosh and Windows can be downloaded free from our web site at <http://members.aol.com/FoveaPro/> along with this information sheet, and can be installed and used without restriction. However, the plug-in cannot be redistributed or included in any compilations without prior written permission, nor may it be modified, de-compiled, or otherwise altered by users.

Reindeer Games 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 capabilities to read several specialized image formats, for only \$649.95. Tool Kit users can trade up to FoveaPro for a reduced price. Ordering information is provided on the web site, or you can duplicate and mail in the attached form.

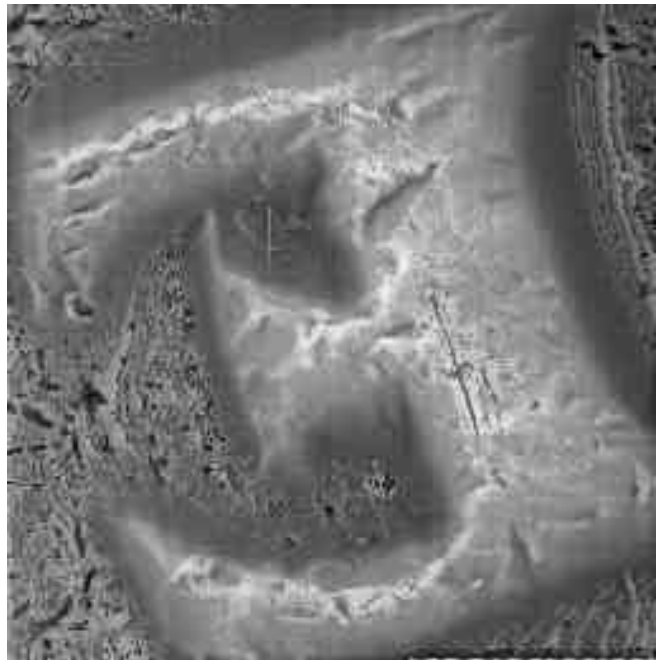


Example 1 - Fingerprint image before and after equalization, shown at 70% of original size.

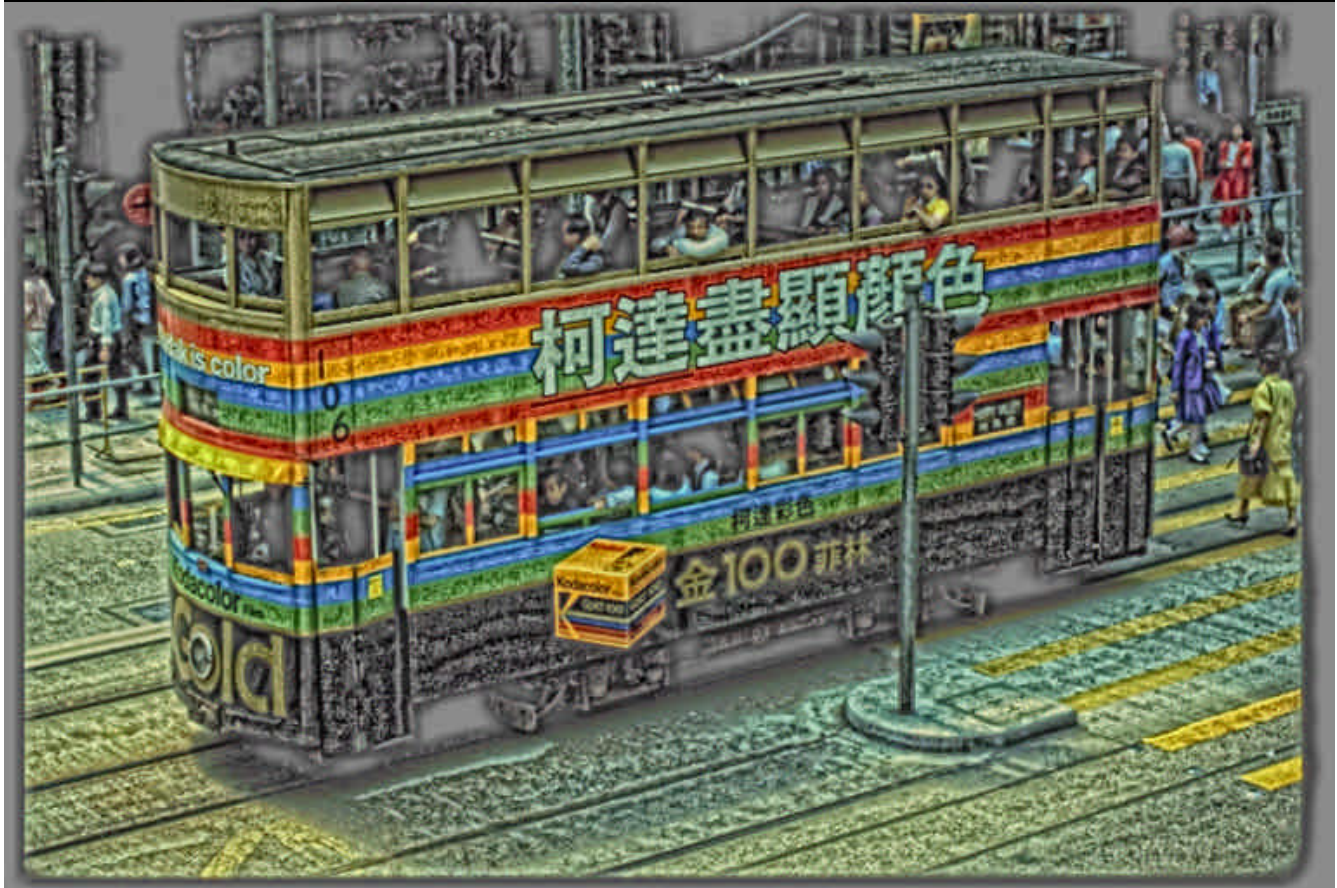




Example 2 - SEM image of dried paint, shown at 45% of original size (photo credit: Pia Wahlberg).



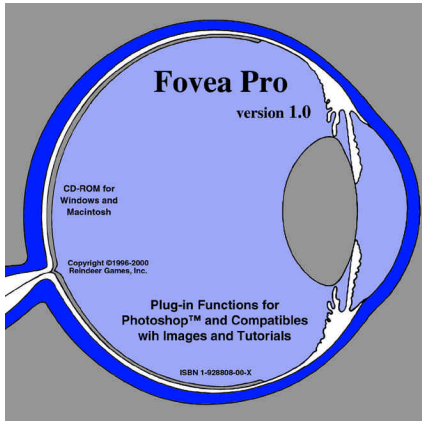
Example 3 - Scanned probe image of coin surface, shown at 95% of original size.



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

Fovea Pro

VERSION 1.0



Complete Tools for Processing and Measuring Images

Chris Russ and John Russ
ISBN 1-928808-00-X
Catalog FOVP10, 2000
CD-ROM \$649.95

Fovea Pro offers a comprehensive set of functions for the computer-based image processing and measurement of 8 and 16 bit grey scale and 24 and 48 bit RGB color images.

Taking advantage of the power of modern desktop computers, Fovea Pro comprises an indispensable set of Photoshop™ compatible plug-ins that deliver an impressive array of tools to help you process and measure your images. Within the familiar environment of Photoshop 5 (running on either the Mac or Windows computers) you will have access to analytical power and functionality that exceeds many "professional" dedicated image analysis programs that cost ten times more!

In addition, the Fovea Pro CD includes a complete hands-on course in image analysis that guides you through the use of the various functions, illustrates them with images that are supplied on the disk, and in effect provides a college-level course in image analysis that you can follow at your own pace, or dip into when you need the answer to a particular problem. The tutorial ("The Image Processing and Analysis Cookbook") is a 400+ page lavishly illustrated book in pdf

(Acrobat) format on the CD, along with more than 300 test images that you can use for practice.

Fovea Pro requires only a modest technical background in imaging and computers, but the routines are professionally written to the highest standards and correspond exactly to the methods described in "The Image Processing Handbook," 3rd edition, by John C. Russ (CRC Press, 1998, isbn 0-8493-2532-3).

The plug-ins on the disk (more than 150 in all) provide comprehensive tools for

- Image Adjustment** - leveling contrast and brightness, removing background, performing rotational alignment, histogram equalization and other modifications
- Color Manipulation** - working in various color spaces, correcting color shifts, extracting and inserting color planes, processing images in HSI space
- Image Math** - add, subtract, multiply, divide, brightest, darkest, etc.
- Boolean Operations** - and, or, ex-or, not, masking, plus a unique feature-and that operates on features rather than just pixels
- Fourier Processing** - forward and inverse transforms, filtering, cross-correlation, deconvolution
- Morphological Operations** - erosion, dilation, opening, closing, skeletonization, hit-or-miss, top-hat and rolling ball filters, in user-adjustable neighborhoods
- Neighborhood Processing** - an extensive variety of state-of-the-art edge extraction, noise reduction, texture isolation, contrast enhancement, and orientation finding algorithms, many rarely found on small computer systems
- Distance-Map Operations** - erosion and dilation, openings and closing with isotropic results, and without a doubt the best watershed segmentation routine around, eliminating the subdivision of lines and other common defects
- Thresholding** - manual and automatic routines, working directly in HSI space for color images, with a selection of algorithms to select optimum threshold levels or draw contour maps

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- Automation** - full recording of all functions and entered values in Photoshop Actions.

Fovea Pro runs on both Mac and Windows computers. It extends the recognized and widely used capabilities of The Image Processing Tool Kit (isbn 1-928808-00-X) to deal with 16 bit grey scale and 48 bit RGB color images, which Photoshop 5 can display but for which there are essentially no other processing or measurement tools available. These high-depth images are essential for many scientific imaging tasks, and are provided by some microscopes, cooled digital cameras, and flat bed scanners.

Fovea Pro is also compatible with many other programs for Mac and Windows computers that handle 8 bit greyscale and 24 bit RGB images, and support the plug-in interface, such as Paint Shop Pro, NIH-Image, Canvas, Image-Pro Plus, etc.

Visit our web site for more detailed information and an ordering info: <http://members.aol.com/FoveaPro/>

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