Photoshop Plugins for Image Processing and Analysis

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These 39 plugins provide important added functionality for Adobe Photoshop CS4 and CS5 Extended (they will run with all recent Photoshop versions, but those two are preferred for image analysis as they include built-in measurement capabilities). Photoshop functions can provide a significant amount of image processing and measurement capability, but there are gaps in performance which these routines are designed to fill. See below for restrictions regarding their use.

The plugins require running in 32 bit mode. They can be applied to gray scale or RGB color images, either 8 bits or 16 bits per channel. They can also be applied to a selected single channel of a color image (including Lab color) as a gray scale image. The entire image area is processed, ignoring any regions that may be defined. However, if a region has been established, any changes to the image will only appear within the region.

Download and unzip either the Macintosh or Windows version and place the folder with its contents in Photoshop's Filters folder:

On the Mac, the location is **Applications | Adobe Photoshop CS5 (or CS4) | Plug-ins | Filters**;
Under Windows, the location is **Applications | Adobe Photoshop CS5 (or CS4) | Plug-ins | Filters**.

When Photoshop is next launched it will read the contents of the folder and will create three new entries in the Filter menu, each of which has sub-menu entries arranged alphabetically:

_Binary Image	_Combine Images	_Measure Features	_Process Image
Apply Automatic Threshold	Add Reference Image	Count Black Features	Center-Weighted Brightness
Distance Map Black Features	Cross-Correlate Ref. Image	Feature Numbers	Conditional Gaussian Filter
Fill Holes in Features	Keep Darker Pixel Values	Feature Size and Shape	Convert to Int-Hue-Sat
Morphological Closing	Keep Lighter Pixel Values	Generate Line Grids	Homomorphic Range Comp.
Morphological Opening	Ratio to Reference Image	Total Area Fraction	Hybrid Median Filter
Outline Black Features	Store Reference Image	Total Perimeter	Kuwahara Filter
Prune Skeleton Branches	Subtract Reference Image		Level Background Shading
Shade Small Features by Area	Use Ref. Image as Markers		Local Equalization
Skeletonize Black Features			Local Variance
Skeleton End Points			Principal Color Components
Watershed Feature Separation			Rank Sharpening Filter
			Sobel Gradient Filter
			Sobel Orientation Filter
			Top Hat Brightness Difference

A brief description of each function is given below. These plugins can be incorporated in Photoshop Actions. In addition to the use of these plugins in the workshops taught by the author, these methods are covered in books such as those listed below. These include information on the algorithms used and the rationale for their application, as well as programming code. Many other texts also describe these methods and their use, not always with the same names.

For information on other useful sets of plugins, see the section at the bottom of this file.

_Binary Image

These functions are normally applied after an image has been thresholded to black and white, with the black pixels representing structures, objects or features of interest and the white representing background. This is the same convention as that used throughout Photoshop. Some other programs use the opposite convention of white features and black background. Any pixels with values darker than 128 are treated as features, and vice versa.

Apply Automatic Threshold: Applies a thresholding operation to the brightness values of a gray scale or RGB color image (for a color image, the average of the red, green and blue) and produces a black and white binary result. In many applications, this is faster and more reproducible than manual thresholding with Image->Adjustments->Threshold.

***Distance Map Black Features*:** Each pixel within a feature is assigned a gray scale value that represents the distance to the nearest point in the background. The result is autoscaled for features in which values would exceed 255. This result is called the Euclidean Distance Map or EDM. It is useful for some measurements, either of feature dimensions (the maximum value represents the radius of the largest inscribed circle) or separation distances (by inverting contrast so that it is performed on the background), often by combining this image with the skeleton. Thresholding the distance map of features or background is an efficient and accurate way to perform erosion and dilation, and is used in the Morphological Closing and Morphological Opening plugins described below.

Fill Holes in Features: Holes contained within features are filled in. "Holes" that intersect the boundary of the image are not filled in, as there is no information from beyond the boundaries to indicate whether they are closed or not. Since features are treated as contiguous for pixels that touch at corners or sides (8-connectedness), the background is treated as contiguous only for pixels that touch along sides (4-connectedness). This allows, for instance, a feature outline to be filled.

Morphological Closing: Performs a dilation followed by an erosion, using the distance map to achieve isotropic results with an accurate distance value (equal for the dilation and erosion). The user must specify the distance (in pixels, but not limited to integer values). The Windows version allows direct entry in a dialog. The Mac version requires the presence of a plain text file named Distance.txt on the desktop containing the numeric value (see the note below about text files).

Morphological Opening: Performs an erosion followed by a dilation, using the distance map to achieve isotropic results with an accurate distance value (equal for the dilation and erosion). The user must specify the distance (in pixels, but not limited to integer values). The Windows version allows direct entry in a dialog. The Mac version requires the presence of a plain text file named Distance.txt on the desktop containing the numeric value (see the note below about text files).

***Outline Black Features*:** The pixels along the boundaries of the feature are shown as black lines, with everything else white. This is useful for measurements, for determining where regions touch (by applying it to different images or channels and then combining them), and for outlining objects in images for display purposes (by combining the outlines with the original image).

Prune Skeleton Branches: When a skeleton is used to represent a network (e.g., cell walls, grain boundaries), the tesselation should have no branches that end. Pruning removes such branches. In some instances, depending on the geometry of the skeleton, it may be necessary to repeat the skeletonization and pruning once to achieve a

clean result. The difference between the skeleton and the pruned skeleton can be used to isolate just the terminal branches.

Shade Small Features by Area: Measures the area of each feature in the image and shows features smaller than 250 pixels with shades of gray proportional to the size. This allows small features typically resulting from dirt or noise to be rejected by thresholding with Image -> Adjustments -> Threshold. A setting of 255 will keep all existing features. Reducing the threshold setting will progressively remove larger ones. Features that touch any boundary of the image are eliminated as they cannot be measured.

***Skeletonize Black Features*:** The skeleton is a set of lines that represent the basic topology (which can be described by the number of end points, number of branches and number of nodes). The skeleton can also be used to select ridge lines in the distance map. The count of nodes and end points is reported; the node count may not be reliable because the skeleton of two lines crossing at a low angle may result in two nodes. Intersections of the skeleton with the image borders are not counted as ends.

Skeleton End Points: After skeletonizing, this function selects just the end points (points with a single neighbor). These may be used for counting, as markers, and for other purposes.

***Watershed Feature Separation*:** In many cases, touching or slightly overlapped convex features can be separated (white lines drawn between them) using this routine. This uses the distance map to locate the boundaries.

_Combine Images

These routines provide ways to combine two images together, pixel by pixel. In all cases, the "reference image" is stored beforehand (it is placed into a special disk file) and is not modified by the operation. In Windows the file location is the root of C:\, which must be accessible. The images remains in the file until a new reference image is stored. The reference image and the current image must have the same dimensions; it is not required that they have the same mode (grayscale, RGB, 8 bit or 16 bit).

***Add Reference Image*:** The two sets of values are added together, replacing the original. The result is automatically scaled so that the darkest value is exactly black and the brightest exactly white. If these limits correspond to only a few pixels, manual or automatic levels adjustment (Image -> Adjustments -> Levels) can be applied afterwards to expand the contrast. When applied to two binary images, the result can be thresholded to obtain the Boolean AND (threshold below 128) or OR (threshold above 128) combinations.

***Cross-Correlate Ref. Image*:** This routine is primarily used for finding matching patterns. The reference image should contain a target (centered and cropped) to be located in the current image. The resulting image has brightness values that indicate the degree to which the patterns match at each location. This is usually easier to interpret with gray scale rather than color images. An easy way to create the target image is File -> New and select the existing image in the drop-down Preset menu. Paste the target, which will automatically be centered; Layers -> Merge Layers; Store Reference Image; select the image to be processed. Then use Cross-Correlate Ref. Image. The images must be square, with dimensions in pixels equal to an exact power of 2 (128, 256, 512, 1024, ...)

***Keep Darker Pixel Values*:** The two sets of values are compared, and whichever pixel value is darker is kept. This is particularly useful for inserting lines such as skeletons or outlines to an original image.

***Keep Lighter Pixel Values*:** The two sets of values are compared, and whichever pixel value is lighter is kept. This is particularly useful for eliminating background regions from the original image. It can also be used to combine a skeleton with a distance map, combine multiple outlines to locate common regions, etc.

***Ratio to Reference Image*:** The ratio of the brightness of each pixel in the current image to the corresponding one in the reference image is calculated and replaces the original. The results are scaled to fill the brightness range of the image. This is particularly useful for leveling uneven background lighting when the objects of interest can be removed and a second image acquired. Depending on how the camera records brightness, either this function or Subtract Reference Image will be the preferred method.

***Store Reference Image*:** The current image is written to a special disk file so that it can be used in the other routines in this group. The image is not modified by any of the operations in this group, and remains in the file until replaced by another image.

***Subtract Reference Image*:** The difference between the brightness of each pixel in the current image and the corresponding one in the reference image is calculated and replaces the original. The results are scaled to fill the brightness range of the image. This is particularly useful for leveling uneven background lighting when the objects of interest can be removed and a second image taken. Depending on how the camera records brightness, either this function or Ratio to Reference Image will be the preferred method.

Use Ref. Image as Markers: Any black pixels (i.e. darker than 128) in the reference image become the seeds for dilation that is constrained by the black features in the current image. The result is to select features in the current image that are marked by pixels in the reference image. Because constrained dilation is slow for large or complexly shaped features, this function may take some time, and in any event is terminated after 1000 dilations. It is very useful for selecting features based on touching lines (outlines, for instance), characteristic internal points (e.g., cell nuclei), or grids of points.

_Measure Features

These routines provide measurement capabilities that supplement the functionality of the Photoshop Analysis menu. They treat any pixels darker than 128 as part of features to be measured, and any brighter pixels as background. Pixels are considered to be part of the same feature if the touch along their sides or at their corners (this 8-connected rule is different that Photoshop's 4-connected rule in which regions are contiguous only if the pixels share an edge).

Count Black Features: The number of contiguous groups of pixels is counted and reported. Pixels are considered touching if either their sides or corners are adjacent. Features that touch any boundary of the image are not included. If you want to count these, use Select -> All and Edit -> Stroke to draw a one-pixel wide white line around the image boundaries. To count features that touch only two contiguous edges, shift the image one pixel to the right and down (Select -> All, hold down the Control/Command key and press the arrow keys).

Feature Numbers: Applies brightness shading to the features to indicate their ID numbers as recorded by the Feature Size and Shape function. Placing the cursor over the feature shows the value in the Info palette. For image with more than 100 features, the numbers cycle from 1 to 100 again. Because the built-in Photoshop conversion to gray scale shades alters pixel values, the results should be examined as RGB values.

Feature Size and Shape: This routine measures the area and perimeter of each feature, and from them calculates a value for circularity (defined as in the Photoshop measurements as 4π Area / Perimeter^2). The resulting data are written to a file named Size+Shape.txt. This is a plain text file containing tab-delimited values,

which can be opened in most word processors, spreadsheet programs, and statistics packages. The Mac version writes the file to the desktop. The Windows version writes the file to the root of the C:\ drive (write permission is required). In addition to the data output, the features are color coded according to the circularity values (colors vary from red for the highest value to orange, yellow, green, blue and magenta for lower values). Note that the measurement values are not identical to those reported by the Photoshop Analysis->Record Measurements function, which measures things differently. The region boundaries lie around features rather than passing through the centers of the border pixels, and pixels are considered to be part of the same feature only if they share sides (4-connectedness) rather than also including corner-touching (8-connectedness).

Generate Line Grids: Grids of lines are used for many different types of measurements, typically by combining them with the thresholded binary image or an outline image using an AND, followed by measurement or counting. Four types of grids are provided: parallel vertical lines, squares, concentric circles, and cycloids. A user-supplied spacing value (in pixels) controls the distance between the lines, and for the cycloids the radius of the generating circle. The selection of the grid type and the spacing are each entered in a dialog for the Windows version, and read from a plain text file named Grids.txt on the desktop for the Mac version (see the note below about text files). The parallel lines can be rotated to any angle using the Photoshop Image -> Image Rotation -> Arbitrary function (use Bicubic interpolation and then apply skeletonization). Depending on the spacing value, the circle and cycloid grids will include a few doubled pixels due to limited arithmetic precision (apply skeletonization). The length of grid lines can be measured using the Filter -> _Measure Features -> Measure Total Perimeter function (this reports twice the actual length in pixels, since it measures along both sides of each line). The square line grid can be converted to a point grid using Filter -> Noise -> Median.

Total Area Fraction: The percentage of the image that consists of black pixels (i.e., darker than 128) is reported, along with the total image area in pixels.

Total Perimeter: The total length of the perimeter around all black features (i.e. darker than 128) is reported in pixels. The calculation uses the chain-code length of the boundary. The intersections of features with the image boundaries are not included, and they are not actual feature perimeter. For measuring lines, the line length is half of the perimeter (which runs along both sides).

About text files on the Macintosh: The input files used to enter control parameters on the Macintosh must be plain text. Unfortunately, it is possible to have a file with the correct name (e.g., Grids.txt) that is not plain text but contains some formatting information. Sometimes the attempt to read parameters from an improperly formatted file can crash the plugin and/or Photoshop! Programs such as TextEdit do NOT create proper plain text files, even if Format->Make Plain Text is applied, but TextEdit CAN open, edit and save them. Example files Grids.txt and Distance.txt are provided with the plugins, and can be placed on the desktop, edited and saved using TextEdit.

_Process Image

These functions supplement the image processing routines built into Photoshop (such as Gaussian Blur, Median Filter, Unsharp Mask, Maximum, Minimum [also called erosion and dilation], Curves or Levels adjustment, etc.). They provide additional levels of functionality and results, based on advanced, well established algorithms.

Center-Weighted Histogram: This modifies the pixel brightness values to change the brightness histogram to an approximately Gaussian, centered shape. It is useful as a supplement to the Photoshop Adjustments -> Equalize routine and particularly suitable for high contrast and high dynamic range images, to assist in on-screen viewing

or printing. Similar effects can be produced with the Image -> Adjustments -> Curves function but this does not require manual manipulation.

Conditional Gaussian Filter: In order to reduce random speckle noise without degrading steps and edges, the weight of the Gaussian smoothing is adjusted according to the difference between the pixel and its neighbors. This approach is also known as a Bilateral filter.

Convert to Int-Hue-Sat: The channel values in an RGB Color image are converted to Intensity, Hue and Saturation. The channel names are not changed in this process, so it is necessary to be careful in using the converted image. The IHS color channels are often useful for thresholding and other processing, as an alternative to Photoshop's Lab space.

***Homomorphic Range Compression*:** High contrast images generally cannot be printed or viewed on the screen to show details in both the bright and dark regions. Homomorphic compression uses frequency processing and log space to compress the overall contrast range while preserving local contrast so that the details are more visually apparent.

***Hybrid Median Filter*:** The conventional median filter fills in fine lines and rounds corners. The hybrid median does not. Median routines are the preferred ways to reduce random speckle or dropout image noise. This routine uses a neighborhood that is a 5 pixel wide circle.

***Kuwahara Filter*:** This is also called a maximum likelihood filter. It sharpens edge contrast so that the location of brightness steps is well defined, often useful before thresholding and measurement.

***Level Background Shading*:** Uneven lighting makes subsequent processing and measurement difficult. This routine automatically locates bright or dark points throughout the image (which are assumed to represent the same background structure), fits a polynomial function to those values, and removes the resulting variation from the original image to level the overall brightness (the result is also autoscaled to fill the contrast range). The original set of these plugins (described in The Image Processing Cookbook, Second Edition) lists two plugins, one to level bright background and one for dark background. By examining the statistics of the image histogram, it is usually possible to automatically make that decision, so there is now a single plugin that handles both cases.

***Local Equalization*:** Every pixel in the image is compared to the brightness of pixels in a 9 pixel wide circle around it. If the pixel is brighter than most of its neighbors, it is made brighter still (and vice versa). The result eliminates changes in average brightness from one portion of the image to another, while retaining and enhancing local contrast to show local detail.

***Local Variance*:** The statistical variance of the brightness values of pixels in a 7 pixel wide circular neighborhood is calculated, and replaces the original pixel brightness value. In some cases this is a useful edge delineation tool, and in others it is a good detector of texture.

***Principal Components*:** Principal Components Analysis (PCA) is applied to the RGB channels of the image to find the linear combinations that correspond best to the actual colors that are present. These are then computed, pixel by pixel, and assigned to the red, green and blue channels respectively. This approach is often useful for increasing the visibility of structures that have similar colors. In some cases it is useful to follow this operation with Image -> Adjustments -> Hue/Saturation and rotate the hue setting to obtain colors that are visually more distinct.

***Rank Sharpening Filter*:** Like the Filter -> Sharpen -> Unsharp Mask filter, this routine subtracts a "blurred" copy of the image (in which local detail has been eliminated) from the original, to enhance the visibility of the detail and edges. Instead of using a Gaussian blur, a ranking filter (with a 7 pixel wide circular neighborhood) is used so that the same enhancement is produced in both light and dark regions, and the presence of "halos" around edges that are characteristic of the unsharp mask are avoided.

***Sobel Gradient Magnitude*:** The Sobel filter is widely used for edge or step delineation. It calculates the vector gradient of brightness at each point. This routine assigns the vector magnitude to each pixel. (This can be subsequently thresholded and skeletonized to delineate boundaries.)

***Sobel Gradient Orientation*:** The gradient vector calculated by the Sobel filter also has a direction. This routine assigns that direction to the pixel brightness value. Combining these values with the outline from the Sobel gradient magnitude shows the orientation of boundaries. It can also be used to measure anisotropy in orientations of fibers, etc. The brightness scale 0....255 represents angles from 0...360 degrees.

Top Hat Brightness Difference: The difference between the maximum brightness values in a 3 pixel wide inner neighborhood and a 7 pixel wide annulus surrounding it is assigned to the pixel. This is used to find small bright spots (such as spikes in a Fourier transform power spectrum). To find dark spots, first invert the image. Setting a threshold on the resulting image selects the brightness difference.

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Note: The plugins are based on, and use some of the programming code from, the textbook "Introduction to Image Processing and Analysis" (John Russ & Chris Russ, CRC Press, 2008). The use of this programming code carries the restriction that the resulting programs cannot be sold for profit or redistributed by others (i.e., it is OK to pass along the link but everyone should download their own copy). These plugins may be downloaded from the author's website for personal use without fee by anyone who attends one of the author's workshops or purchases one of his books, but with the request that users send an email with their name and contact information to the author at <DrJohnRuss@GMail.com>, so that they can be apprised of updates (I promise not to sell the names!). The following books are all available at Amazon.com.

J. Russ (2010) The Image Processing Handbook (6th edition), CRC Press (isbn 978-1439840450)
J. Russ (2011) The Image Processing Cookbook (2nd edition), Amazon CreateSpace (isbn 978-1456531010)
J. Russ, C. Russ (2008) Introduction to Image Processing and Analysis, CRC Press (isbn 978-0849370731)
J. Russ (2004) Image Analysis of Food Microstructure, CRC Press (isbn 978-0849322419)

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Some other plugins are available that can extend Photoshop's capabilities to meet the needs of scientific, technical and forensic image processing and analysis. Some are free or very inexpensive. Demo versions of those that are not free are available that will run for a short period of time, or for a limited number of applications.

- **4N6site.com** has a free Fourier transform and inverse transform combination that simplify pattern removal, and an inexpensive color deconvolution routine for removing unwanted colors to reveal a target (e.g., handwriting or fingerprint) of interest. Both are for Windows only.

- **3d4x.ch** (http://www.3d4x.ch/?c=16,35) has free Fourier transform and inverse transform plugins, as well as plugins to convert between RGB and HSL color spaces. For Windows only.

- **ePaperPress.com** has inexpensive PTLens software that can remove image distortions, and includes presets for many camera lenses. For both Windows and Macintosh.

- **TopazLabs.com** has inexpensive Topaz InFocus software for deconvolution of image blur. For both Windows and Macintosh.

- **ReindeerGraphics.com** sells Fovea Pro, a comprehensive but somewhat expensive set of tools that implement specific algorithms appropriate for scientific image processing and measurement, and can log data to facilitate automation. For Windows or Macintosh. From Reindeer Graphics, Inc., P.O. Box 2281, Asheville, NC 28802, 919-342-0209. Note: this site also offers a free download of the Wide Histogram plugin.

- **OceanSystems.com** sells ClearID, an expensive workflow-oriented set of image processing tools marketed for forensic images. For Windows only. From Ocean Systems, Inc., 4016 Blackburn Ln., Burtonsville, MD 20866, 301-476-8015

- **Pluginsite.com** lists a huge number of free plugins (for both Windows and Mac), some of which may be useful in particular situations. There are many sites with plugins, actions and scripts (most of them unsuitable for technical applications) that can be found with Google.