

NIH Image 1.54

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INTRODUCTION

NIH *Image* is a public domain image processing and analysis program for the Macintosh. It can acquire, display, edit, enhance, analyze, print and animate images. It reads and writes TIFF, PICT, PICS and MacPaint files, providing compatibility with many other applications, including programs for scanning, processing, editing, publishing and analyzing images. It supports many standard image processing functions, including contrast enhancement, density profiling, smoothing, sharpening, edge detection, median filtering, and spatial convolution with user defined kernels up to 63x63. *Image* also incorporates a Pascal-like macro programming language, providing the ability to automate complex, and frequently repetitive, processing tasks.

Image can be used to measure area, average gray value, center and angle of orientation of a user defined regions of interest. It also performs automated particle analysis and can be used to measure path lengths and angles.

Measurement results can be printed, exported to text files, or copied to the Clipboard.

Spatial calibration is supported to provide real world area and length measurements. Density calibration can be done against radiation or optical density standards using user specified units. The user can select from any of eight different curve fitting methods for generating calibration curves.

Image provides MacPaint-like editing of color and gray scale images, including the ability to draw lines, rectangles, ovals and text. It can flip, rotate, invert and scale selections. It supports multiple windows and 8 levels of magnification. All editing, filtering, and measurement functions operate at any level of magnification and are undoable.

Image supports Data Translation and Scion frame grabber cards for capturing images or movie sequences using a TV camera. Acquired gray scale images can be shading corrected and frame averaged.

Image is written using Think Pascal from Symantec Corporation, and the complete source code is freely available.

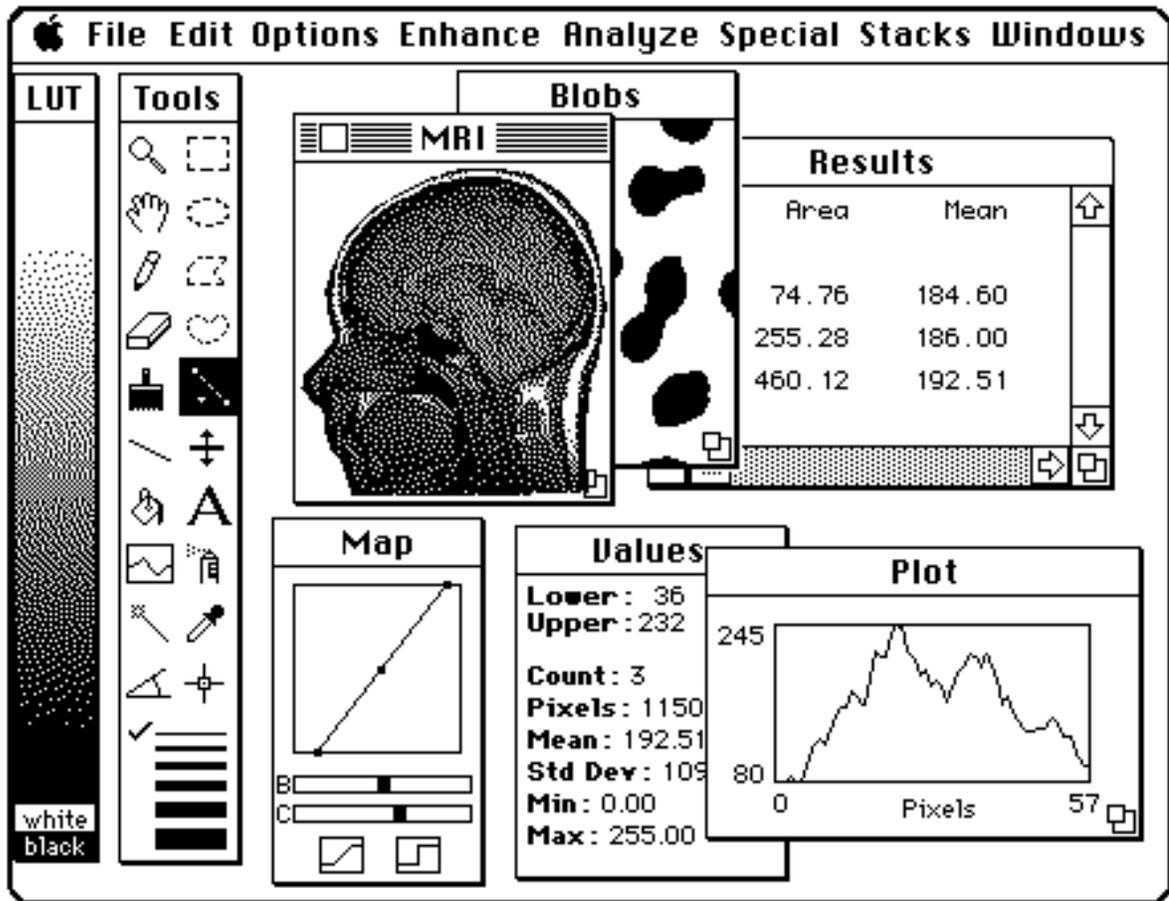
System Requirements

Image requires a Macintosh with at least 4MB of memory, but 8MB or more are recommended for working with 3D images, 24-bit color or animation sequences. It requires a monitor with the ability to display 256 colors or shades of gray. *Image* directly supports, or is compatible with, large monitors, flatbed scanners, film recorders, graphics tablets, PostScript laser printers, photo typesetters and color printers.

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OVERVIEW



Windows

Image displays images, measurement results, profile plots, etc. in windows. Windows can be dragged around the screen by their title bars. In addition, some windows can be resized (e.g. the Plot window) using the “drag box” in their lower right corner. A window buried underneath other windows can be activated by selecting it in the Windows menu.

The LUT window displays the current video look-up table. The Tools window contains a palette of tools for making selections, editing images, drawing text, and making measurements. The Map window is used for adjusting the contrast and brightness of images and for enabling and disabling thresholding. The Values window displays the most recent measurement results. The Results window displays the current table of measurement results. The Plot window displays density profile and calibration plots. The currently active window (e.g., the MRI window above) has a highlighted menu bar.

Images

Image manipulates, displays and analyses images. Images are two dimensional arrays of pixels (picture elements). Pixels are represented by 8-bit unsigned integers, ranging in value from 0 to 255. *Image* follows the Macintosh convention and displays zero pixels as white and those with a value of 255 as black. 16-bit images can be imported and scaled to

8-bits. The 16-bit (up to 65,000 gray levels) to 8-bit (256 gray levels) scaling can be controlled by the user or performed automatically based on the minimum and maximum gray values in the 16-bit image. The Rescale command (in the File menu) allows the user to redo the 16-bit to 8-bit scaling at a later time.

Stacks

Image supports the organization and manipulation of a series of 2D images as a 3D array called a stack. A stack contains a set of related 2D images, such as a movie loop or serial sections from a volume. The 2D images that make up a stack are called slices. You can step through the slices using the “>” and “<” keys. The number of the current slice and the total number of slices are displayed in the title bar. The Stacks menu contains commands that work with stacks. Windows to Stack converts a set of 2D images into a stack. Animate animates the images in a stack at a rate up to 100 frames per second. Reslice reconstructs a new 2D image perpendicular to the plane of the slices in a stack. Project does volume rendering, which is useful for visualizing the internal structures of 3D images. Commands not in the Stacks menu, except for Open, Save and Export, have no knowledge of stacks. For example, the Invert command only inverts the current slice, not the entire stack. Macros are available, however, for performing various operations on all the slices in a stack.

Memory Requirements

Opened images are stored entirely in the Mac’s internal memory, or RAM (Random Access Memory). An image requires one byte of RAM for each pixel plus a few thousand additional bytes for data structures containing information about the image, such as color tables and calibration. For example, a 512 X 512 image requires 262,144 bytes, or 262K, where 1K equals 1024 bytes. A 256 X 256 X 256 stack would require 16,777,216 bytes or 16MB. To see how much RAM an image uses, use the Get Info command, or pull down the Windows menu, which shows the size of all open images.

The number and size of images that *Image* can work with depends on *Image*’s RAM allocation. To check or change the allocation, select *Image*’s icon (a microscope) and use the Finder’s Get Info command. The default allocation is 2500K. To use all of *Image*’s features requires a RAM allocation at least three times the size of the largest image, plus the size of the program (about 300K). The extra RAM is for a buffer used to support one level of Undo (the Undo Buffer) and a Clipboard buffer. The default size of these buffers is 300K. This can be changed using the Preferences command in the Options menu. You can find out how much memory is currently available for opening images by selecting “About Image” from the Apple menu.

File Formats

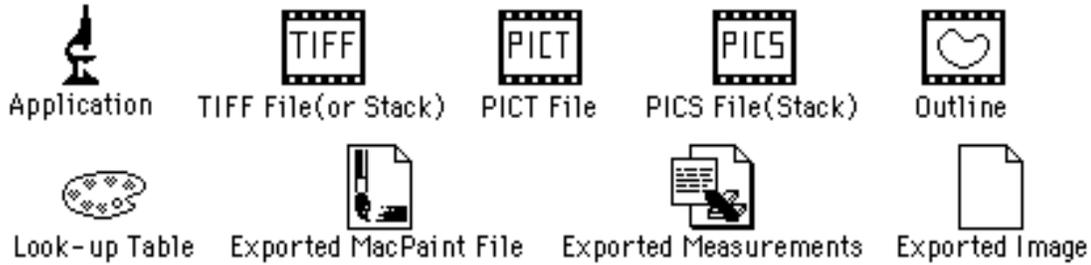


Image supports TIFF, PICT, PICS and MacPaint file formats. Stacks can be saved as either multiple image TIFF files or as a PICS file. The Import and Export commands allow images with arbitrary binary and tab-delimited (spreadsheet) formats to be read and written. The Open All option of the Open and Import commands allows a series of images to be read automatically. Measurement results can be exported to a text file compatible with spreadsheet and statistical analysis programs.

Macros

Image can be extended using a Pascal-like macro programming language. The easiest way to develop a custom macro is to modify one of the macros in the Macros folder distributed with *Image*. Macros are stored in text files that can be edited using *Image*'s built-in text editor. Using the Load Macros command causes the macros in the file to appear as commands at the bottom of the Special menu. The macro language is described in Appendix A. The description assumes some familiarity with the Pascal programming language. Additional help on macro writing, and other ways to extend *Image*, can be found in a separate document named "Inside Image".

Plug-ins

Image can also be extended using Photoshop compatible plug-ins. Acquisition plug-ins are used to support scanners or frame grabbers, or to read images in file formats that *Image* does not normally support. They are accessed using the Acquire sub-menu. Export plug-ins are used to output to printers that do not have a Chooser selectable driver or to save images in file formats not normally supported by *Image*. They are accessed using the Export sub-menu. Filter plug-ins perform filtering operations on images. They are accessed using the PlugIn Filters sub-menu. *Image* expects to find plug-ins in a folder named Plug-ins located in either the same folder as *Image* or in the System folder. You must be using System 7 to use plug-ins.

Video Capture

Using a frame grabber card, *Image* can digitize images from TV cameras, VCRs or video disks. Captured frames can be averaged or summed. The Histogram command will display a continuously updated density histogram during "live"

capture. The Make Movie command will capture a sequence of frames into a stack at rates up to 15 frames per second. The Capture Color command digitizes 24-bit color into a three slice stack. For alignment purposes, Show Paste Control (in the Windows menu) allows “Live” video to be superimposed over a previously captured image. Information about the two frame grabber cards directly supported by *Image* (the Scion LG-3 and the Data Translation Quick Capture) is given in Appendix B.

Image Enhancement

The Enhance menu provides filters for smoothing, sharpening, finding edges and reducing noise in images. The Convolve command uses user-defined filters that operate

on up to 63X63 neighborhoods. The Binary sub-menu's Make Binary command converts grayscale images to images consisting of only black and white pixels and includes commands to process such images. Use the Arithmetic sub-menu to add or multiply an image (or selection) by a constant. Addition or subtraction of two images is done using the Image Math command or by clicking on Add or Subtract in the Paste Control dialog box while doing a paste operation.

Making Measurements



To make a manual area measurement, first outline a region of interest using the rectangular, oval, polygonal, or freehand selection tool. Then select the Measure command, which will compute the area, mean gray value, and the minimum and maximum gray value. Other measurements, such as perimeter, can be enabled using the Options command in the Analysis menu. Measure distances by making a straight, freehand or segmented line selection, and then using the measure command. Use the angle tool to measure angles. The cross hair tool counts objects, marks them, and records their X-Y coordinates. The wand tools automatically outlines structures isolated using thresholding. Results from the most recent measurement are displayed in the Values window. Use Show Results to display a table of results since the last time the Reset command was used.

The Analyze Particles command automatically counts and measures features of interest. This requires thresholding to discriminate objects of interest from surrounding background based on their gray values. *Image* has two thresholding methods. In thresholding mode (Threshold is checked in the Options menu), all pixels equal to or greater than a single threshold level are displayed in black, and all other pixels (the background) are displayed in white. In Density Slicing mode (Density Slice is checked), all pixels between a lower and upper threshold are highlighted in red. For both modes, you adjust threshold levels by dragging the LUT tool (the one with the double-headed arrow) in the LUT window. For successful thresholding, it may be necessary to use the Subtract Background command to remove the effects of uneven illumination.

Images can be calibrated to either spatial or density standards using the Set Scale and Calibrate commands respectively. To calibrate spatially, use the line selection tool to measure a known distance, then use Set Scale to specify a unit of measurement (e.g. millimeters) and enter the known distance. To calibrate to a set of density standards (e.g. an optical density step tablet), measure the mean gray level of each of the standards, then use the Calibrate command to enter the known values and specify the type of curve fit.

Editing



Image's tool palette contains several tools used for image editing and annotation. The pencil, brush, line, paint bucket and spray can draw in the current foreground color, which is shown in the brush icon. The text tool draws text using the current font, size, style, and foreground color. Click with the eyedropper tool on a color to select a new foreground color. The eraser tool erases to the current background color, as shown in the eraser icon. Click with the eraser on a color in the LUT window to select a new background color.

Commands in the Edit menu operate on the current selection. Cut, Copy and Paste perform the standard Macintosh Clipboard operations. Fill fills the selection in the foreground color. Clear erases it to the background color. Draw Boundary draws a line

around the selection. Scale and Rotate enlarges, shrinks and/or rotates the selection. Commands are also available for flipping and rotating by 90°.

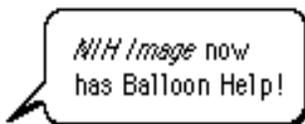
Text Windows

Image has a built-in text editor that can open and edit text files up to 32K in size. The following command know how to deal with text windows: New, Open, Close, Save, Save As, Print, Cut, Copy, Paste, Clear, Font, Size, Convolve (uses the kernel in the current text window), and Load Macros (loads the macros contained in the current text window). Also note that the Fill command changes to Find when a text window is active.

Look-up Tables

Each open image has a look-up table (LUT) associated with it. The LUT for the currently active image is used to map, at video rates, pixels (in the range 0-255) to screen colors. The LUT window displays the contents of the look-up table for the currently active image. Click and drag with the LUT tool in the LUT window to adjust brightness and contrast. Measured density values will not change since you are manipulating the look-up table, not the image's pixel values.

Various commands at the top of the Options menu allow you to invert the current LUT, to specify the number of gray levels or colors it uses, or to switch to one of several built-in color tables. LUTs are automatically stored with an image when it is saved to disk, or they can also be saved separately.



On-line Help

Balloon help is available in the Tools, Map and LUT windows, in menu commands, and in most dialog boxes. Balloon help is enabled by selecting Show Balloons from the Help (?) menu. The Tools, Map and LUT windows must be activated (by clicking on them) to get the help messages to appear. Balloon help is only available when using System 7.

NIH Image Mailing List

No telephone support is available for *Image*. The NIH *Image* mailing list, however, provides a way to get questions answered. It can also be used to contact other users, to keep abreast of new developments, and to get *Image* updates via e-mail. To subscribe, send an e-mail message containing the single line

subscribe nih-image <first name> <last name>

to listserv@soils.umn.edu. If you get tired of being bombarded with a dozen e-mail messages a day, you can remove yourself from the list by sending a message containing the line "unsubscribe nih-image" to listserv@soils.umn.edu. There is also an option to receive messages as a once per day digest. All past messages are archived and available via e-mail, FTP and Gopher. Instructions on how to retrieve archived messages is in the welcome message sent at subscription time. The mailing list, which currently has 534 subscribers, is run by the Soil Science Department at the University of Minnesota. Information on other ways to get updates, and on how to report bugs, is given in Appendix I.

Citing NIH Image

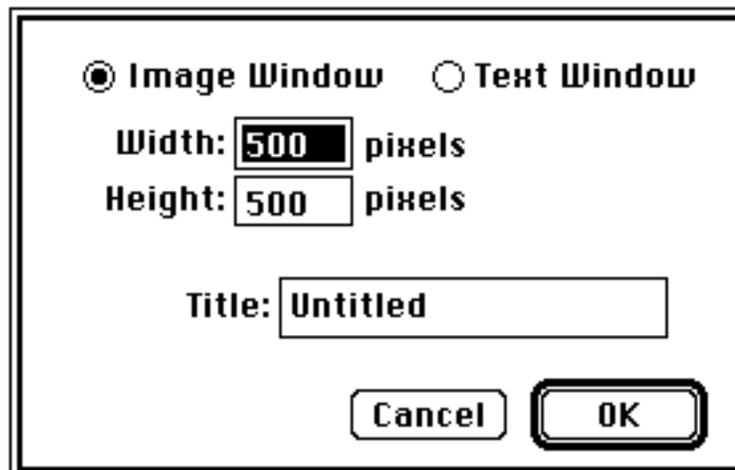
Published research assisted by this software should use the following quote when mentioning *Image* in the materials and methods section "... analysis performed on a Macintosh <model> computer using the public domain NIH Image program (written by Wayne Rasband at the U.S. National Institutes of Health and available from the Internet by anonymous ftp from zippy.nimh.nih.gov or on floppy disk from NTIS, 5285 Port Royal Rd., Springfield, VA 22161, part number PB93-504868)". To appear in a medline search the words "NIH Image" must appear in either the abstract or the Keywords index.

MENUS

File Menu

New

Creates a new image or text window. Image windows are filled with the current background color. New image windows inherit the look-up table, as well as any spatial or density calibration, of the currently active image window. Text windows can be used to create macros that are accessed using the Load Macros command or convolution kernels that can be used by the Convolve command. Text windows have a maximum size of 32K.

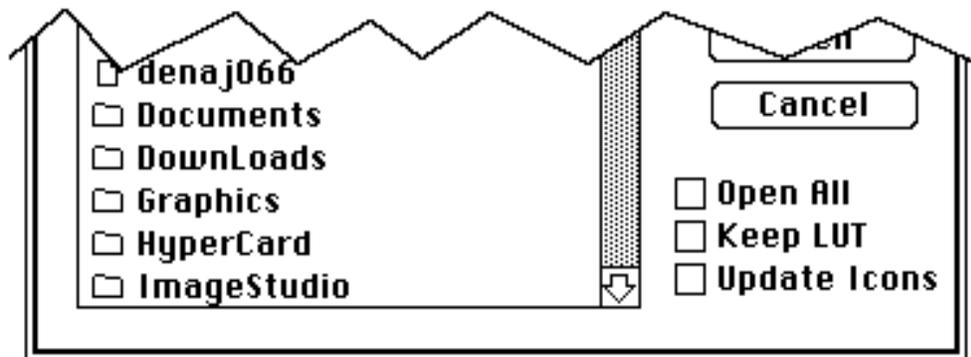


Open...

Use the Open command to load and display images (in TIFF, PICT, PICS and MacPaint format), text files, color look-up tables (LUTs) or region of interest outlines. The following file types are supported:

- 1) TIFF files created by *Image* and many other programs. *Image* will open (as a stack) a TIFF file containing multiple images, but the images must all have the same width and height. *Image* is unable to open bitmap (1-bit), 24-bit color, or compressed TIFF files. TIFF files that were created on other systems, such as an IBM-PC, usually need to be opened using the Import command. 16-bit TIFF files can be opened using the Import command.

- 2) PICT files created by *Image* and numerous other Macintosh programs. Check *Keep LUT* in the Open dialog box (shown below) if you want to display the image using the current palette, instead of the one contained in the PICT file.
- 3) MacPaint documents. You will want to set *Undo Buffer Size* in Preferences to 405K if you regularly open large MacPaint drawings, since this is the memory required for a full size (576 x 720) MacPaint document.
- 4) PICS files created by *Image* and by many Macintosh animation programs.
- 5) Look-up tables created by *Image* and by several other Macintosh programs, including PixelPaint, Canvas, UltraPaint, and the Klutz DA. PixelPaint, Canvas and UltraPaint have palette editors that can be used to create color tables for use by *Image* . The public domain PalEdit program from NCSA may also be used to create color tables that can be opened by *Image*.
- 6) Selection outlines created by using the Save As command in *Image*.
- 6) Text files, such as macros and convolution kernels, up to 32K in size.



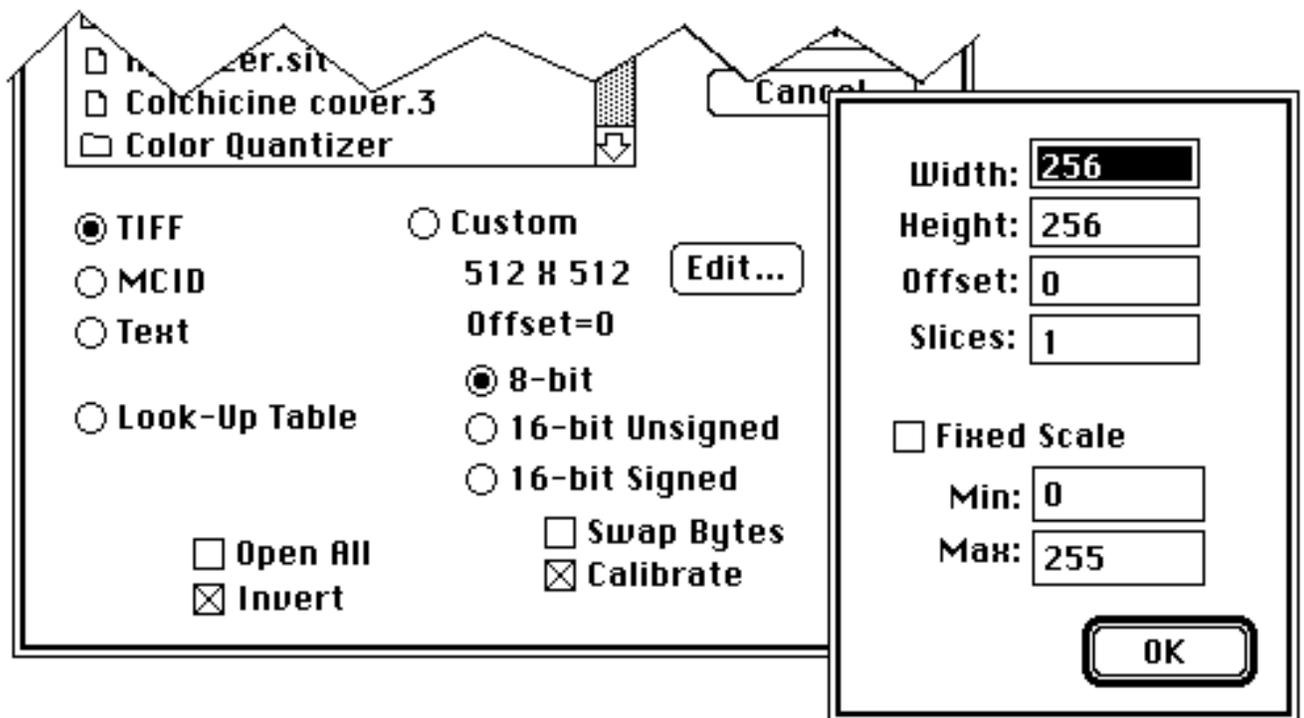
If you check *Open All*, select an image, and then click on the Open button, *Image* will open all the images in that folder, not just the one selected.

Check *Keep LUT* if you want the image to be displayed using the current video look-up table, rather than the one saved with the image. This feature can be used to combine PICT files with different palettes into a montage. When the PICT file is opened, and the image and screen LUTs are different, the pixel values are remapped to make the colors consistent.

The *Update Icons* check box is used for updating documents created by older versions of *Image*. No files are opened if this option is selected. Instead, all files in the currently selected folder with a creator type of 'IMAG' have their creator type changed to 'Imag'. 'IMAG' is the creator type used by versions of *image* earlier than 1.41. Files with the new 'Imag' creator type have icons with a white background and launch the latest version of *Image* when you double-click on them.

Import...

Use the Import command to read image files created by non-Macintosh based systems, to display spreadsheet data (text) as an image, or to import raw color look-up tables. It presents a dialog box that allows you to select the type of file to be imported.



Select *TIFF* to open 8 and 16-bit TIFF files imported from other systems, such as an IBM PC. Once a 16-bit TIFF file has been imported, you can use Rescale (aka Revert to Saved) to find the optimum 16-bit to 8-bit mapping. 16-bit TIFF files that represent white as zero open inverted.

Select *MCID* to opens files compatible with the IBM-PC based MCID image analysis system from Imaging Research. The MCID format, which is very simple, is described in Appendix E.

Select *Text* to import a two-dimensional array of numbers stored in tab-delimited text format, for example, a spreadsheet saved as “Text Only”. Values do not have to be in the range 0-255, and may be in decimal or scientific format. By reading in the text file twice, *image* is able to determine the number of rows and columns, and to scale to 8-bits (1-254). Blank cells are assumed to have a value of zero. If *Fixed Scale* is checked then automatic scaling is disabled, values are scaled to the range *Min-Max*, values less than *Min* are set to *Min*, and values greater than *Max* are set to *Max*.

Select *Look-Up Table* to import a 768 byte binary LUT consisting of 256 consecutive red values, 256 consecutive green values, and 256 consecutive blue values. The values should be in the range 0-255.

Select *Custom* to open other types of 8-bit and 16-bit binary images. *Width* is the width of the image in pixels and *Height* is the number of lines in the image. For 16-bit images, the maximum value that can be entered for *Width* is 4096. *Offset* specifies the number of bytes *Image* will skip before it starts reading the pixel

data. For example, use an offset of 512 to skip over a 512 byte file header. Set *Slices* to more than one to import 3D data sets such as multi-slice volumes from medical scanners

Image computes the minimum and maximum pixel values of 16-bit images and uses this information to linearly scale to 8-bits (1-254). Check *Swap Bytes* if you are importing 16-bit images from “little-endian” systems, such as the IBM-PC, PDP-11 or VAX. If *Calibrate* is checked *Image* automatically sets up a linear density calibration function to

provide an approximation of the original 16-bit pixel values. The approximated values should not vary from the original 16-bit values by more than $(\text{Max}-\text{Min})/254$, where Min and Max are the minimum and maximum 16-bit values. If *Fixed Scale* is checked then automatic scaling is disabled and the 16-bit data is linearly scaled from *Min-Max* to 1-254. You can redo the 16-bit to 8-bit scaling at any time using the Rescale command.

The Import command can be used to convert 16-bit images from medical scanners to the 8-bit format required by *Image*. For example, to import raw MRI scans from a GE SIGNA scanner, set *width* and *height* to 256, select *16-bit Signed*, and set *Offset* to 14336. The macro “Import GE Signa Files” (in the file Stacks) will automatically import a series of raw GE SIGNA files.

Check *Open All* to import all of the images in a folder. Images must all have the same width, height, etc. *Open All* does not work with imported text files and palettes.

Check *Invert* to invert imported 8-bit images.

Close

Closes the currently active image, text, Plot, or Histogram window, i.e., the one with the highlighted title bar. Hold down the Option key to close all currently open image windows. Typing Option-Command-W or Option-Clicking in the close box of an image window will also close all the image windows. When closing many windows, pressing command-period will bypass intermediate screen updates, causing the windows to close quicker.

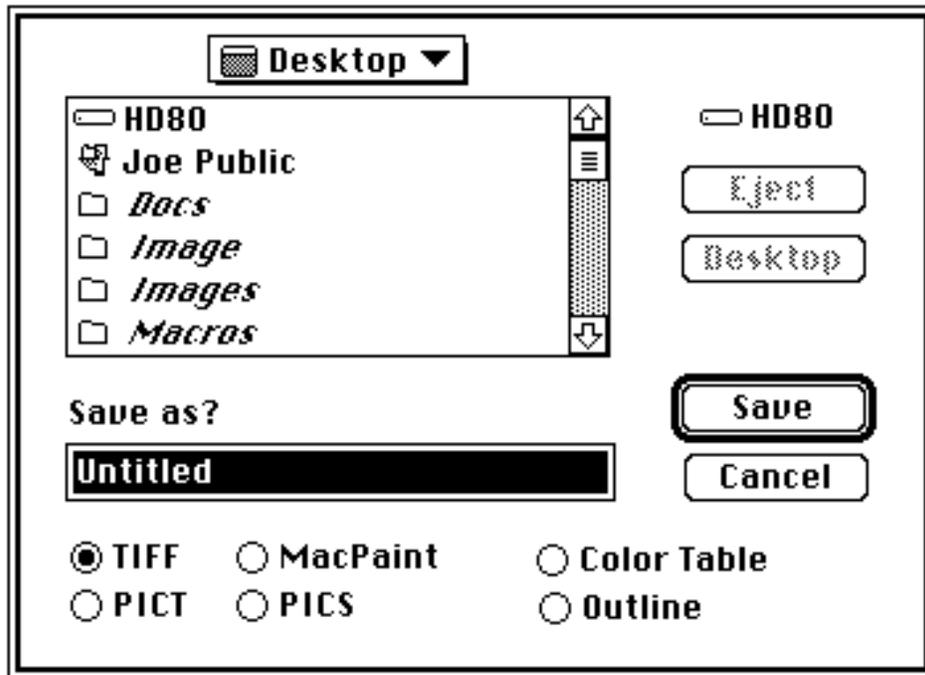
Save

Resaves the currently active image or text window to the disk. In the case of an image window that was newly created using New, Duplicate or Start Capturing, you will be prompted for a name. Files are resaved in their original format. In other words, TIFF files are resaved in TIFF format, and PICT files are resaved in PICT format.

Hold down the Option key (notice how Save changes to Save All) to save all currently open image windows.

Save As...

Allows you to save the currently active image (or rectangular selection) in TIFF, PICT or MacPaint) format, to save a stack in TIFF or PICS format, or to save the current look-up table or outline. The Save As command is also used to save the current text window.



TIFF

Saves the currently active image or stack to a file in uncompressed 8-bit TIFF format. You will be asked to enter a name for the new file. The menu command changes to Save Selection As if a rectangular selection is active, allowing you to save a subsection of the image. Note that the ability to save selections does not work for stacks, but there are macros available to get around this limitation. TIFF is the default file format in *Image*, and is usually the best format for saving digitized or scanned images. Because TIFF files are not compressed, they usually Open and Save faster than PICT files.

PICT

Saves the currently active image to a PICT file. PICT files can be exported to many other Mac programs, including Canvas, Photoshop, SuperPaint and MacDraw. Because they are compressed, PICT files also have the advantage of being more compact if the image contains large homogeneous regions, which is typical of computer generated images. Unfortunately, the run length compression scheme used with PICT files is ineffective with most scanned images.

You should avoid PICT files if you are doing quantitative image analysis.

The Mac imaging model is most concerned with the color of each pixel, and does not care so much about the actual pixel value. Thus PICT files cannot guarantee that the pixel values remain fixed. TIFF is a machine and system independent image standard that avoids this problem.

MacPaint

Saves the currently active image as a MacPaint document. Since MacPaint images are binary (black and white only), you will probably want use Dither or Make Binary to convert grayscale images to binary before saving them.

PICS

Saves the currently active stack to disk in PICS format, a file format supported by many Mac animation programs. PICS files are compressed using the same run length encoding scheme used for PICT files. Stacks containing areas of uniform color or gray value saved in PICS format will be smaller than stacks saved in TIFF format. Utilities are available for converting from PICS to QuickTime, including a free one available by anonymous ftp from zippy.nimh.nih.gov, in the /pub/nih-image/programs directory.

Color Table

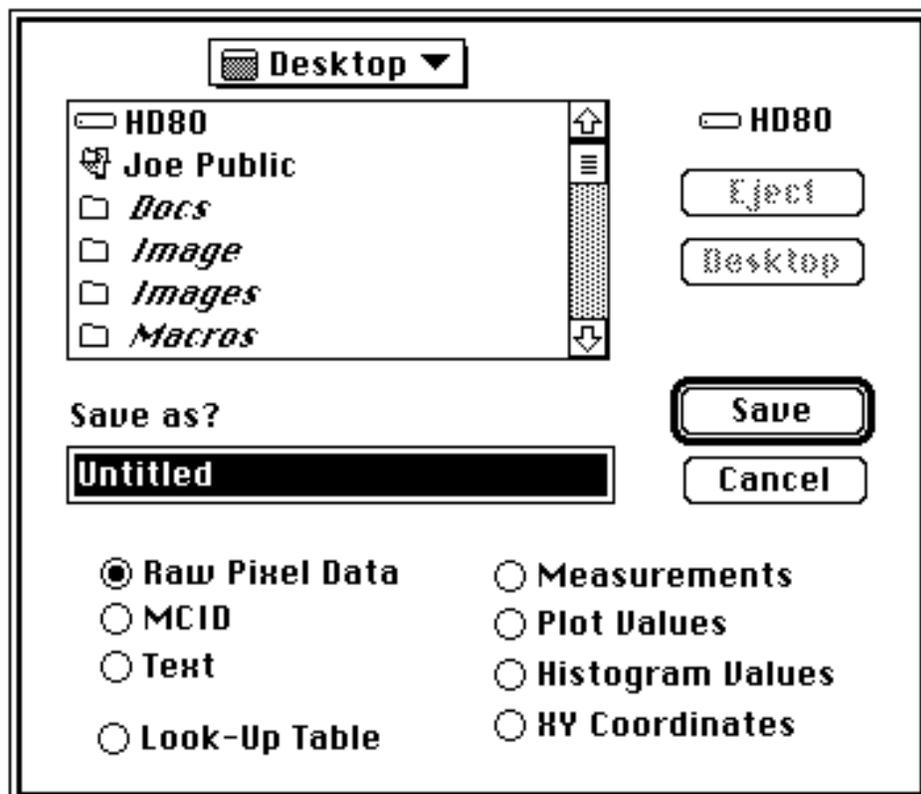
Saves the current look-up table.

Outline

Saves the X-Y coordinates of the current selection outline. X-Y coordinates of curved line selections, and selections that have been edited, can not be saved.

Export...

Exports images, look-up tables, measurement results, density profile plot values, or histogram values to disk for use with programs other than *Image*.



Raw Pixel Data

Exports the current image (or selection) as binary pixel data, in row order, one byte per pixel, without a header.

MCID

Exports the current image (or selection) as an MCID file. MCID files have the same format as raw pixel data files, but are preceded by a four byte header which

contains the width (minus one) and height (minus one), stored as two 16-bit numbers in Intel byte order.

Text

Exports the current image (or rectangular selection) as a tab-delimited, spreadsheet compatible text file consisting of uncalibrated pixel values.

Look-Up Table

Saves the current video Look-Up Table (LUT) as a 768 byte file consisting of 256 red values, 256 green values, and 256 blue values.

Measurements

Exports the current measurements to a tab-delimited text file compatible with spreadsheet and statistical analysis programs. Use the Analyze/Options dialog box to specify which measurements are recorded and/or exported. This option is also used to export angle measurements made with the angle tool, and X-Y coordinate measurements made with the cross hair tool. Measurements can also be exported by copying them to the Clipboard.

Plot Values

Exports the data values representing the most recent density profile to a text file. If you have just used the Calibrate command to do density calibration, and are viewing the density calibration plot, then this option exports the 256 Y-values of the current calibration plot.

Histogram Values

Exports the 256 gray level counts from the most recent histogram to a text file.

X-Y Coordinates

Exports the X-Y coordinates of the current selection outline as a two column, tab-delimited text file. X-Y coordinates of selections that have been edited can not be exported.

Save Screen

Saves the contents of the entire screen, including menu bar, trash can etc., to a PICT file named *Screen* in the same folder as *Image*. Any existing file with that name will be replaced without warning.

Record Preferences

Saves the current state of the following *Image* program parameters. Settings are saved in a file named *Image Prefs* in the System Folder. You can revert to the default settings by deleting this file and restarting *Image*.

- Foreground color
- Background color
- Brush size
- Airbrush diameter
- Color Look-Up Table mode
- Color palette position and width
- Text attributes, including font, size, style and justification
- Extra colors
- Invert Video switch
- Measurement Options

- Profile Plot Options
- Frames averaged by Average Frames command
- Size of image created by New command
- Undo (and Clipboard) buffer size
- Frame grabber input channel
- Import command options
- Most options in the Preferences dialog box

Revert to Saved

Reverts to the most recently saved version of the current image, effectively undoing all changes made since the last Save command. Reverting does not currently work with stacks or imported text files. For imported 16-bit images, this command changes to Rescale, described below.

Rescale

Replaces Revert to Saved whenever an imported 16-bit image or imported 16-bit TIFF file is active. This command linearly scales the 16-bit data (on disk) from the range *Min-Max* to 1-254, where *Min* and *Max* are determined by using the controls in the Map window or by using the LUT tool. 16-bit pixels with values less than *Min* are set to 1 and 16-bit pixels with values greater than *Max* are set to 254. The computed absolute minimum and maximum pixel values are used if the LUT has not been altered.

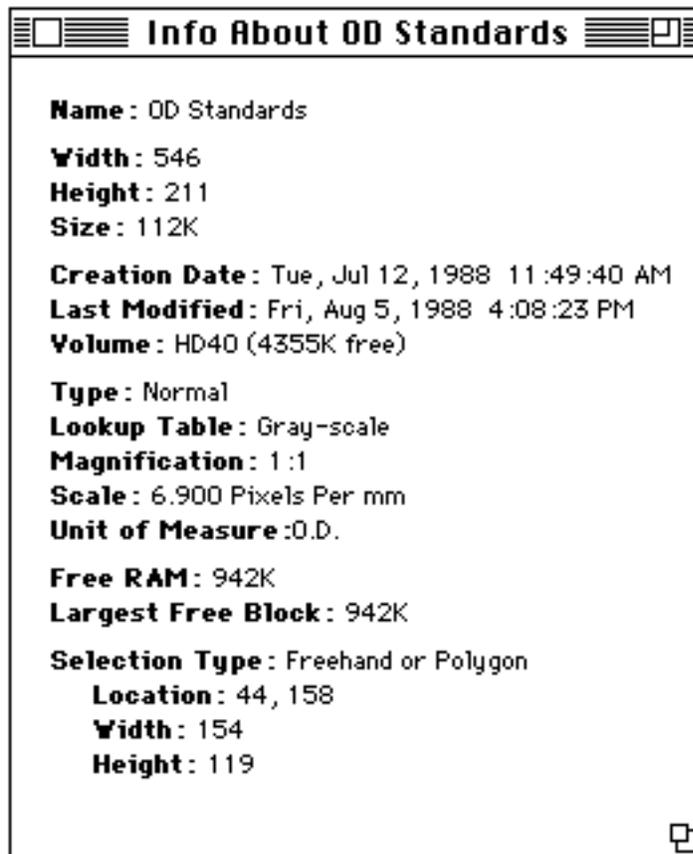
The *Highlight Saturated Pixels* option in the Preferences dialog box can be used to determine locations within the image where density measurements may be invalid due to clipping at *Min* or *Max*. It causes pixels that were less than or equal to *Min* to be displayed in yellow and pixels that were greater than or equal to *Max* to be displayed in red.

Duplicate

Creates a new window displaying a copy of the current image, or of the current selection if only part of the image is selected. The newly created image inherits the look-up table, plus any spatial or density calibration, of the image being duplicated.

Get Info

Displays an image window, such as the one below, giving information about the currently active image and about the status of the system.



Acquire

Use this sub-menu to access Photoshop compatible acquisition plug-ins. The plug-ins must be stored in a folder named "Plug-ins" located either in the same folder as *Image* or in the System Folder. Using plug-ins, *Image* can acquire 8-bit grayscale, 8-bit indexed color, and 24-bit color images. 24-bit color images are stored in three slice stacks and displayed using 8-bit indexed color, similar to the way the Capture Color command works. Several of the plug-in listed below, including "Plug-in Digitizer" for use with the AV Macs, are available by anonymous FTP from zippy.nimh.nih.gov, in the /pub/nih-image/plug-ins directory.

The following plug-ins have been reported to work with *Image*:

Agfa PhotoScan

Canon CLC 500 Color Laser Copier with Electronics for Imaging interface

Computer Eyes /RT Pro

Datacopy 730GS scanner

Ektron 1400 series camera (Eikonix 4096x4096 CCD)

Graphics Unlimited Kingfisher frame grabber (grayscale only)
Howtek II slide scanner
La Cie SilverScanner (8-bit grayscale, 8-bit color, 24-bit color)
Kodak DCS-100 and DCS-200 digital cameras (grayscale and 24-bit color)
Kodak Photo CD Image Browser
Kodak RFS2035 scanner

MacVision video capture
Microtek Scanmaker
MirrorScan 600 Plus
Neotech Image Grabber
Perceptics PixelBuffer frame grabber
Perceptics MegaGrabber frame grabber
Perceptics PixelHR-24 frame grabber
Plug-in Digitizer (supports AV Macs and other QuickTime digitizers)
QuickImage 24 plug-in
Radius VideoVision video grabber
RasterOps Video Capture V1.51 with 24STV and 24XLTV cards
Scantastic plug-in with Apple Color One scanner
Scion LG-3 frame grabber
Sharp JX-325 scanner
Truvel scanner
Umax UC630 scanner
Voyager decompression plug-in

Export

Use this sub-menu to access Photoshop compatible export plug-ins. Export plug-ins must be stored in a folder named "Plug-ins" located either in the same folder as *Image* or in the System Folder. Two export plug-ins have been successfully tested with *Image*: a plug-in that supports the Scion TV-3 video output card (used to drive a video printer) and the PhaserPrint plug-in for the Tektronix Phaser IIsd dye sublimation printer.

Halftone Options...

Allows you to specify how halftoning is done on the LaserWriter or other PostScript printers. Halftoning is a technique which allows grayscale images to be printed on a device whose pixels can only be black or white. This is accomplished by dividing the printer pixels into small groups (or cells) according to some pattern (called the halftone screen). Within each cell, a dot is drawn whose size is proportional to the gray value of that part of the image. A screen frequency of about 50 halftone cells per inch, providing a cell size of 6 x 6 pixels, is optimum for a 300 dots per inch laser printer. A frequency of 106 is optimum for the LaserWriter IIf (with expanded memory) and LaserWriter IIg printers. Custom halftoning options can be saved using Record Preferences. Note that these settings have no effect if *Custom Grayscale Halftoning* is not selected in the Preferences dialog box.

Page Setup...

Lets you specify printing orientation (portrait or landscape) and scale (25% to 400%). The quality of density profile and calibration plots will be better if you

leave the scale set at 100% and enlarge the plot window before printing the plot. You will not be able to take advantage of special effects, such as Graphics Smoothing, if *Custom Grayscale Halftoning* has been selected in Preferences.

Print...

Print images, text, plots, histograms, and the results of measurements. What gets printed is determined by which window is currently active. The print command changes (e.g., *Print Image*, *Print Plot*, etc.) depending on what kind of window is currently active.

Print Image - Prints the currently active image using digital halftoning to simulate shades of gray. Pixels in color images are converted to grayscale prior to printing using the equivalent of *Convert to Grayscale*, a variation of the *Apple LUT*

command. If you have made a rectangular selection, only the selection will be printed. Images larger than the printer page (normally 552 x 730 pixels) are automatically scaled to fit the page, except when *Custom Grayscale Halftoning* is enabled.

On color printers and film recorders, the output will be centered on the page (or slide). You must deselect *Custom Grayscale Halftoning* in Preferences (or hold the Option key down) when printing on color PostScript printers. Use the Dither command to simulate shades of gray when printing on non-PostScript printers, such as the ImageWriter.

Print Plot - Prints the current density profile or calibration plot. The size of the printed plot is proportional to the size of the plot window, which can be made large using the “grow box” in the lower right corner.

Print Histogram - Prints the contents of the histogram window.

Print Measurements - Prints the results of measurements made with the Measure command, or with the angle or the cross hair tools. This command is enabled when you have recorded one or more measurements and either the Values or Results window are active.

Print Text - Prints the contents of the current text window. Text is always printed using 9-point Monaco.

Quit

Closes all image windows after asking, in each case, whether changes made during the session should be saved, then quits to the Finder. If measurements have been made, but not saved, a dialog box will be displayed notifying you of that fact. The Save Changes dialog boxes will not be displayed if you hold down the Command and Period keys while quitting, and any changes will not be saved. Pressing command-period also bypasses intermediate screen updates, causing windows to close more quickly.

Edit Menu

Undo

Reverses the effect of the last editing or filtering operation. When using the Measure command, Undo deletes the most recent measurements.

Cut

Copies the contents of the current image selection to the Clipboard and fills it with the current background color. For text windows, the currently selected text is copied to the Clipboard and the selection is deleted.

Copy

Places a copy of the contents of the current image selection on the Clipboard. *Image* will beep at you if you attempt to copy from an image that is larger than the Clipboard buffer. One work around is to first duplicate the selection.

Copy will also copy the entire contents of the LUT, Plot or Histogram window to the Clipboard if one of these is the active window. If the Plot or Histogram window is active

then both the data values and graphics will be copied to the Clipboard, allowing you to transfer plot and histogram data to other programs for plotting or statistical analysis. For text windows, the currently selected text is copied to the Clipboard.

Use the eyedropper tool to select a color to be copied from the LUT window to the Clipboard. This color can then be pasted back into another location in the LUT window. Copy and paste of LUT colors works best with look-up table that have 32 or fewer colors.

After using the Measure command, Copy changes to Copy Measurement, allowing you to use the Command-C keyboard shortcut to copy measurements to the clipboard.

Paste

Displays the contents of the Clipboard in the currently active image window. The pasted object is automatically selected, allowing you to move it by clicking and dragging. With rectangular objects, you can click and drag on the resize handle in the lower left corner to expand or contract the selection.

You can also use the paste command to paste colors copied with the eyedropper tool back into the LUT window or to paste text into a text window.

If you make a rectangular selection in the Camera window, copy it to the Clipboard, paste into another window (without deleting the Camera window), and select *Live Paste* in the Paste Control window, then pasting will be “live”. This feature, along with the ability to select different transfer modes, allows the image currently being digitized to be aligned with a previously digitized image.

Text as well as images can be pasted into Image windows. For example, you can copy measurement results to the Clipboard, then paste them into an image window. The text will be displayed inside the current rectangular selection, or, if there is no selection, into a default selection. Use sub-menus in the Option menu to select font, size, style, etc. If the text doesn't fit within the selection, Undo, switch to a different font or size (or make a different selection), and try pasting again. Text background is always erased to white, the “No Background” option in the Style menu is ignored. This is not a problem, however, since you can select the Or transfer mode in the Paste Control window to paste text transparently. When pasting text in the Or mode, you can click in the LUT window to change color or gray level.

Clear

Erases the current image selection to the current background color. The Delete key is a handy shortcut for this command. The background color is set by

clicking with the eraser tool in the LUT window. The color of the eraser indicates the current background color. Deletes the current selection if the current window is a text window.

Fill (or Find)

Fills the current region or line selection with the current foreground color. You can change the color after the selection has been filled by clicking in the LUT window. The entire image window is filled if no selection is active. The foreground color is set by clicking with the eyedropper tool in the LUT window or in the active image window. The color of the brush in the tool palette indicates the current foreground color.

The Fill command turns into Find whenever a text window is active. Type Option-Command-F to repeatedly search for the same string.

Invert

Inverts the contents of the current selection, or the entire image if no selection is active.

Draw Boundary

Outlines the current selection (including line selections) using the current foreground color and line width. Both the color and line width can be dynamically changed as long as the selection is still active.

Draw Scale

Draws a grayscale or color ramp within the current rectangular selection. Use this command to create density calibration scales. You can use Flip Vertical or Flip Horizontal to invert a newly created scale. Look at the file "Demo Macro" for an example of how to use a macro to label a scale created using Draw Scale.

Select All

This command is equivalent to using the rectangular selection tool to select the entire image, including portions that may be offscreen. Once the selection has been made, Select All changes to Deselect All, allowing you to deactivate the selection. You can also deactivate the selection by clicking on any tool other than one of the selection tools, the hand tool, or the magnifying glass.

Rotate Left

Rotates the contents of the current rectangular selection counter-clockwise 90°. Holding the Option key down causes the original object to be erased before being replaced by the rotated version. The entire window is rotated if there is no selection.

Rotate Right

Rotates the contents of the current rectangular selection clockwise 90°. Hold the Option key down to erase before rotating. The entire window is rotated if there is no selection.

Flip Horizontal

Flips the current rectangular selection horizontally around a vertical line through its center. The entire image is flipped horizontally if no selection is in effect.

Flip Vertical

Flips the current rectangular selection upside down. Flips entire image if there is no selection.

Scale and Rotate...

Reduces or enlarges the contents of the current rectangular selection. If *Nearest Neighbor* is checked, scaling is done quickly using pixel replication, but the resulting image may not be smooth. Check *Bilinear* for smoother, but slower, interpolated magnification. Note that bilinear interpolation will probably not work correctly with true color images because of discontinuities in the LUT. If *Angle* is non-zero, the contents of the selection are also rotated the specified number of degrees. Rotation will be clockwise for positive angles and counter-clockwise for negative.

Horizontal Scale (0.05-25): 1.00

Vertical Scale (0.05-25): 1.00

Angle (-180° to 180°): 0.00

Interpolation Method:

Nearest Neighbor

Bilinear

Create New Window

OK Cancel

Show Clipboard

Opens a new window and displays the image currently on the Clipboard. This window, which has the title "Clipboard", will not be updated if the Clipboard later changes.

Options Menu

Grayscale

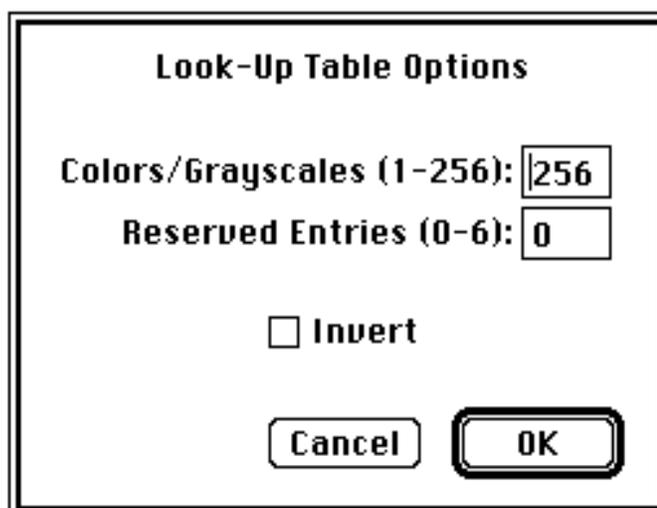
Loads the default grayscale look-up table. Do not use this command to convert 8-bit true color (as opposed to pseudocolor) images to grayscale. Instead, use the Convert to Grayscale variation of the Apply LUT command. The contrast and brightness of grayscale images can be altered by direct manipulation of the transformation function displayed in the Map window. This function can be applied to the pixel data in memory, thereby making contrast and brightness changes permanent, using the Apply LUT command.

Color Tables

Image currently supports nine built-in color look-up tables. In addition, the Open command can be used to load color tables stored in the Look-up Tables folder distributed with *Image*. You can use the LUT tool (the double headed arrow) to both stretch (changing contrast) and shift the colors within the color table. The colors in a color table can be edited by double clicking on them in the LUT window using the eyedropper tool, although this works best with tables containing only a few colors, around 20 or less.

LUT Options...

Allows you to specify the number of distinct colors or shades of gray in the current look-up table, to reserve up to six entries for annotation and graphics, or to invert the look-up table.



Colors/Grayscales is the number of colors or shades of gray used in the current look-up table. When increasing the number of colors, the required new colors are created by interpolating between existing colors. For example, if the current color table consists of the two colors, white and black, setting the number of colors to

64 creates a grayscale palette with 64 shades of gray.

Reserved Entries allows you to allocate up to six entries in the look-up table for colors that are never altered. For example, you could reserve one entry to add color annotation to a grayscale picture. Any extra colors are displayed at the bottom of the LUT window, allowing you to edit them by double-clicking with the eyedropper tool.

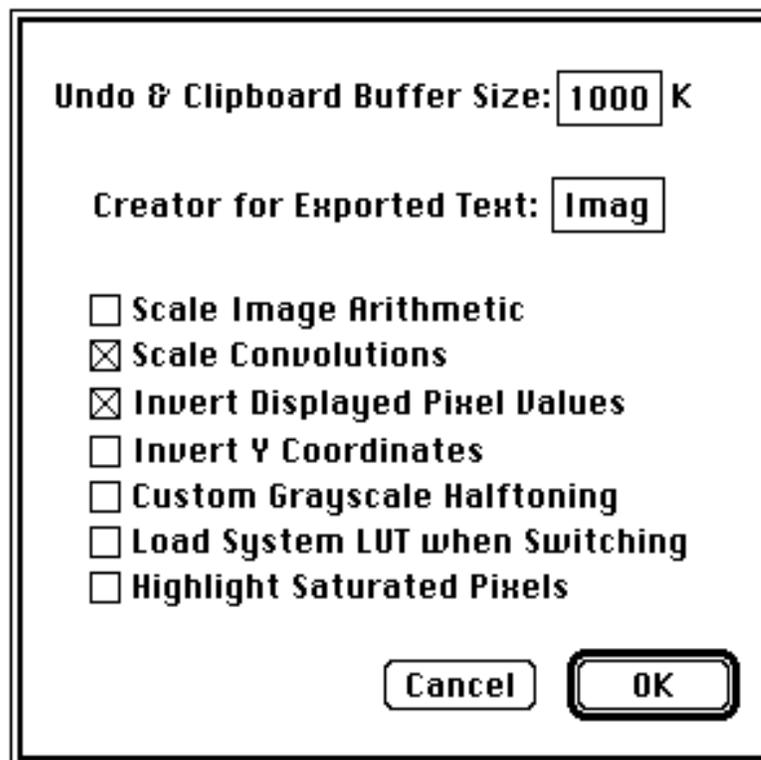
Check *Invert* and the current look-table will be inverted when you click on *OK*. Unlike the Invert command in the File Menu, pixels values are not altered, only the way the image is displayed on the screen. The first (0) and last (255) entries in the LUT, which are always white and black respectively, are never inverted since these entries are used for drawing the menu bar, title bars, dialog boxes, etc.

Font, Size, Style

Text handling in *Image* is similar to Macintosh painting programs such as MacPaint, SuperPaint, and PixelPaint, with the exception that you can only change the characteristics, such as size and style, of the last line entered. You are allowed to change the color (by clicking in the LUT window), size, typeface, style and justification of the current line of text after the text has been entered. The background color can be changed by option-clicking in the LUT window.

Preferences...

Displays the dialog box shown below, allowing you to change various parameters used by *Image* .



Undo & Clipboard Buffer Size allows you to change the size of the two internal image buffers used by *Image*. You must Record Preferences, Quit, and restart *Image* before the buffer size change will take effect.

Creator for Exported Text specifies the four character creator code *Image* uses for exported text files. This code determines which application is launched when you

double-click on an exported text file (e.g., measurements, profile plot data, XY coordinates). Use 'Imag' for Image, 'XCEL' for Excel and 'QKPT' for KaleidaGraph.

Pixel values resulting from Add, Subtract, Multiply, or Divide operations (Paste Control) will be scaled to the range of 0 to 255 if *Scale Image Arithmetic* is checked, otherwise, results are clipped to 0 and 255.

Pixel values resulting from filtering operations done using the Convolve command will be scaled to 8-bits if *Scale Convolutions* is checked, otherwise, they are clipped at 0 and 255.

Checking *Invert Displayed Pixel Values* sets up an inverting linear density calibration function for the current image that causes gray values displayed in the Values and Results windows, in density profile plots, and in histograms, to be inverted. Subsequent image windows created using New, Start Capturing, and the Import of 8-bit images, will inherit this calibration function.

Check *Invert Y Coordinates* if you want the X-Y origin to be the lower left corner of the image window, otherwise it will be the upper left corner.

Check *Custom Grayscale Halftoning* to enable the PostScript halftoning capability built into *Image*. Changes made in the *Halftone Options* dialog box are only effective when this option is selected. Disable this option to use the grayscale and color printing capabilities of LaserWriter driver 6.0 or later. You must disable this option to print on color PostScript printers.

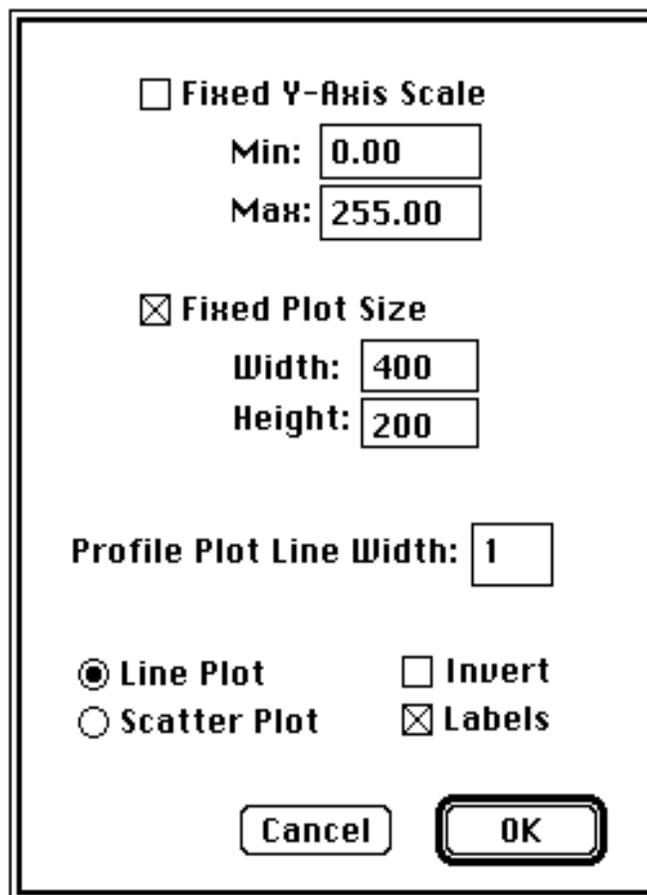
Checking *Load System LUT When Switching* causes *Image* to load the Apple default color palette before switching to other application. This may correct color display problems experienced with other applications, such as Microsoft Excel.

Checking *Highlight Saturated Pixels* causes pixels that are less than or equal to 1 to be displayed as yellow and pixels that are greater than or equal to 254 to be displayed in red.

The status of settings in the Preferences dialog box can be made permanent using the Record Preferences command.

Profile Plot Options...

Displays a dialog box that allows you to set various options relating to density profile plots generated by the profile plot tool and the Plot Profile command. If *Fixed Y-Axis Scale* is checked, the y-axis range is fixed and the specified minimum and maximum are used, otherwise, plots are scaled based on the minimum and maximum gray values. *Fixed Plot Size* allows you to specify the size of the plot window. This is useful when pasting a series of plots that you want to all be the same size into an image window. *Profile Plot Line Width* specifies the line selection width. This controls the amount of pixel averaging done when using the profile plotting tool or the Plot Profile command. All of these settings can be saved using the Record Preferences command.



The dialog box contains the following controls:

- Fixed Y-Axis Scale**
 - Min:
 - Max:
- Fixed Plot Size**
 - Width:
 - Height:
- Profile Plot Line Width:
- Line Plot** **Invert**
- Scatter Plot** **Labels**
-

Scale to Fit Window

Switches the currently active image window in and out of *Scale to Fit* mode. If checked, the window is in the *Scale To Fit* mode, and you can use the “grow box”, in the lower right corner, to rescale the image. Clicking in the “zoom box” at the right end of the title bar will switch that window to *Scale to Fit* mode and scale the window (and image) to fit the screen. In *Scale to Fit* mode, you are not allowed to change the aspect ratio of an image and the magnifying glass and grabber tools do not work. The current magnification level is shown in the title bar of windows in *Scale to Fit* mode.

Threshold

Enables and disables thresholding mode. Thresholding is used to segment an image into objects of interest and background on the bases of gray level. When thresholding is enabled, objects are displayed in black and background is white. The threshold is automatically set based on an analysis of the histogram of the current selection, or of the

entire image if there is no selection. Background pixels will be ignored when making area and gray value measurements using the Measure and Analyze Particles commands. To vary the threshold, use the LUT tool and click and drag near the black/white boundary in the LUT window. As you vary the threshold, its value is continuously displayed in the Values window.

Use the Make Binary command to set all thresholded pixels to black and all background pixels to white. Use the wand tool to outline thresholded objects, and Analyze Particles to automatically measure objects segmented by thresholding. As a shortcut, you can enable thresholding by clicking on the stair step icon in the Map window. This shortcut, however, always sets the threshold to 128.

Density Slice

Enables and disables density slicing. Like thresholding, density slicing allows objects to be segmented on the basis of gray level. When density slicing is enabled, objects are highlighted in red and background pixels are left unchanged. As in thresholding, background pixels are ignored when making area and density measurements. Click and drag in the LUT window using the LUT tool to vary the size and location of the density slice. As you manipulate the density slice, its upper and lower limits are continuously displayed in the Values window.

In the LUT window, you can double click within the density slice using the eyedropper tool to change the highlighting color to something other than the default red. As a shortcut, you can enable density slicing by double clicking on either the wand or LUT tools.

To prevent desktop items, such as the menu bar, from changing color, white (0) and black (255) entries in the LUT are never included within the density slice. Therefore, thresholding usually works better for discriminating objects containing black pixels.

Use the Apply LUT command to set all pixels which are within the density slice to the foreground color (or leave them unchanged) and all other pixels to the background color (or leave them unchanged). The Make Binary command will set pixels within the density slice to black, and all other pixels to white.

Propagate

The commands in this sub-menu allow you to copy various attributes of one image to all other currently open images.

Look-Up Table - Copies the current video look-up table to all open image windows. This provides a way to transfer contrast, brightness or pseudocolor changes made to one image in a set (e.g., a series of MRI scans), to all other images in the set.

Spatial Calibration - The spatial calibration (e.g., pixels/centimeter) and unit of measurement associated with the currently active image are transferred to all other open images. Note that spatially calibrated images have a black diamond in the title bar following the name.

Density Calibration - The density calibration associated with the currently active image is transferred to all other open images. Note that density calibrated images have a white diamond in the title bar following the name.

EnhanceMenu

Filtering Functions (Smooth, Sharpen, etc.)

These functions, with the exception of Reduce Noise and Dither, are implemented using 3 x 3 spatial convolutions, where the value of each pixel in the selection is replaced with the weighted average of its 3 x 3 neighborhood. For correct operation, they require a grayscale image, or a pseudocolored image that started out as a grayscale image. Filtering is not limited to rectangular selections. The entire image will be filtered if no selection is active. Filtering operations can be aborted by typing command-period.

The 3 x 3 tables shown below are the coefficients (weighting factors) for the filters. The popularity of plus and minus one in these tables is due to the fact that multiplication by one is very efficient, i.e., it is unnecessary.

Smooth - Blurs (softens) the selected area. It can be used to reduce noise in an image. Hold the Option key down for increased blurring.

1 1 1	1 1 1 (If Option key down)
1 4 1	1 1 1
1 1 1	1 1 1

Sharpen - Increases contrast and accentuates detail in the selection, but may also accentuate noise. To minimize this problem, you can Smooth and/or *Reduce Noise* before using Sharpen. Hold the Option key down for increased sharpening.

-1 -1 -1	-1 -1 -1 (If Option key down)
-1 12 -1	-1 9 -1
-1 -1 -1	-1 -1 -1

Shadow - Produces a shadow effect, with the light appearing to come from the lower right.

-2 -1 0
-1 1 1
0 1 2

Trace Edges - Produces a binary image with a white background and black outlines representing edges in the original image. Two convolutions are done, generating vertical and horizontal derivatives and the larger of the two result is used. If the resulting pixel is above a threshold value of 35 it is set to black, otherwise it is set to white. You can increase or decrease the number of edges by preprocessing the image. Increasing contrast and Sharpening will increase the number of edges found, decreasing contrast and smoothing do the opposite. Hold down the Option key and the thresholding step will not be done, allowing you to do it yourself.

1	1	1	-1	0	1
0	0	0	-1	0	1
-1	-1	-1	-1	0	1

Reduce Noise - This is a “median filter”, where each pixel is replaced with the median value of its 3 x 3 neighborhood. This is a time consuming operation because, for each pixel in the selection, the nine pixels in the 3x3 neighborhood must be sorted and the center pixel replaced with the median value (the fifth). To demonstrate the effectiveness of median filtering, try removing random spot noise generated using the spray can tool with the diameter set to 50 or greater.

Dither - Uses the Floyd-Steinberg error diffusion algorithm to convert the current selection to a binary (black and white only) image. Dithering can be useful for exporting pictures to applications such as MacPaint or MacDraw that can only accept binary images. Dithering can also be used for printing on the ImageWriter, or other non-PostScript printers. The quality of dithered images can frequently be improved by increasing contrast using the controls in the Map window before doing the dithering. True color images should be converted to grayscale by using the Convert to Grayscale variation of the Apply LUT command before being dithered.

Convolve - Does spatial convolutions using kernels, read from a text file or text window, that can be up to 63 x 63 in size. Use *Image's* built-in text editor to create or examine these kernels.

As an example, use the New command to open a blank text window, enter (or paste) the following kernel, then use the Convolve command to try it out.

```
0 0 0 -1 -1 -1 0 0 0
0 -1 -1 -3 -3 -3 -1 -1 0
0 -1 -3 -3 -1 -3 -3 -1 0
-1 -3 -3 6 13 6 -3 -3 -1
-1 -3 -1 13 24 13 -1 -3 -1
-1 -3 -3 6 13 6 -3 -3 -1
0 -1 -3 -3 -1 -3 -3 -1 0
0 -1 -1 -3 -3 -3 -1 -1 0
0 0 0 -1 -1 -1 0 0 0
```

This is a 9 x 9 “Mexican hat” filter which will do both smoothing and edge detection in one operation. Each line should be terminated with a carriage return, and the coefficients should be separated by one or more spaces, or a tab. Note that kernels, such as this one, can be opened and displayed as an image using the Import (Text) command, scaled to a reasonable size using Scale and Rotate, and plotted using the Surface Plot command.

Plug-in Filters

Use this sub-menu to run Photoshop compatible filter plug-ins. The plug-ins must be stored in a folder named “Plug-ins” located either in the same folder as *Image* or in the System Folder.

Binary

The commands in this sub-menu are used to convert grayscale images to binary

(i.e. black and white only), and to process these binary images. Note that Erode and Dilate do not perform erosion and dilation with structuring elements as described in the literature of classical mathematical morphology. However, several of the Mac image processing programs listed in Appendix D, such as DIP Station, do support mathematical morphology.

Make Binary - Converts the current grayscale image to binary by setting pixels that have been highlighted by either density slicing or by thresholding to black (255), and all other pixels to white (0).

Erode - Removes pixels from the edges of objects in a binary images, where contiguous black areas in the image are considered objects, and background is assumed to be white. A pixel is removed (set to white) if four or more of its eight

neighbors are white. Erosion separates objects that are touching and removes isolated pixels.

Dilate - Adds pixels to the edges of objects in a binary images. A pixel is added (set to black) if four or more of its eight neighbors are black. Dilation connects discontinuous objects and fills in holes.

Open - Performs an erosion operation, followed by dilation, which smooths objects and remove isolated pixels.

Close - Performs a dilation operation, followed by erosion, which smooths objects and fill in small holes.

Set Count... - Allows you to specify the number of adjacent background or foreground pixels necessary before a pixel is removed from or added to the edge of objects during erosion or dilation operations. The default is four.

Set Iterations... - Allows you to specify the number of times erosion, dilation, opening, and closing are performed. The default is one.

Outline - Generates a one pixel wide outline of objects in a binary image.

Skeletonize - Repeatably removes pixels from the edges of objects in a binary image until they are reduced to single pixel wide skeletons. Command-period can be used to abort the thinning process.

Arithmetic

The commands in this sub-menu add (subtract, multiply, etc.) a constant to each pixel in the current rectangular selection, or if there is no selection, the entire image. Results are rounded to the nearest integer.

Add - Adds a constant to each pixel in the selection. Results greater than 255 are set to 255.

Subtract - Subtracts a constant from each pixel in the selection. Results less than 0 are set to 0.

Multiply - Multiplies each pixel in the selection by a constant. Results greater than 255 are set to 255.

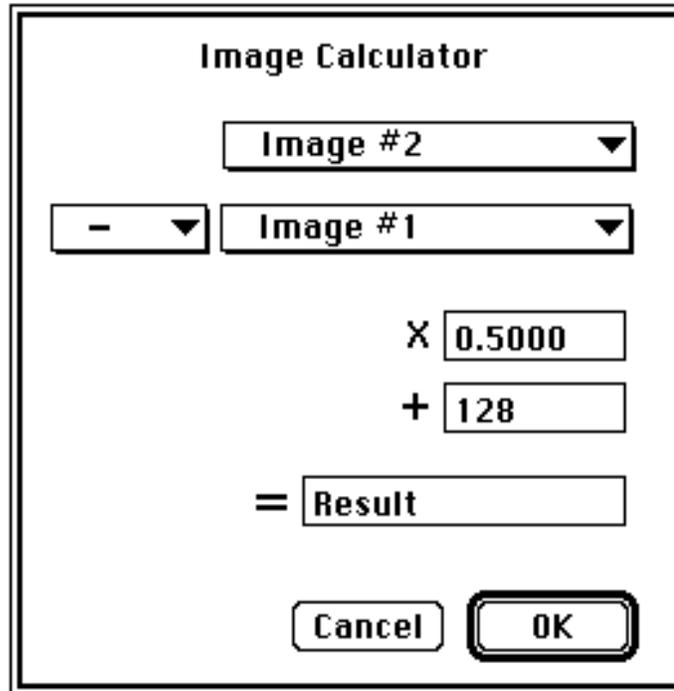
Divide - Divides each pixel in the selection by a constant.

Log - Each pixel (V) in the selection is replaced with $\ln(V) * 255.0 /$

$\ln(255.0)$, where $\ln(V)$ is the natural logarithm(\log_e) of V . The result is set to 0 if V is equal to 0.

Image Math

Performs arithmetic and logical operations between two images selected from pop-up menus. The operation to be performed is also selected from a pop-up menu.



For each pixel in the current rectangular selection, the operation is performed, the result is multiplied by the scale factor, the offset value is added, and the final result is clipped to 8-bits (0-255).

Subtract Background

The commands in this sub-menu remove smooth continuous backgrounds from gels and other images. The rolling ball and rolling disk algorithms used by these routines were inspired by Stanley Sternberg's article, "Biomedical Image Processing", IEEE Computer, January 1983. The routines were written by Michael Castle and Janice Keller of the University of Michigan Mental Health Research Institute.

1D Horizontal - Rolls an arc (rolling arc) horizontally under each row (shrunk 2 or 4 times) of the image in order to remove the background.

1D Vertical - Rolls an arc (rolling arc) vertically under each column (shrunk 2 or 4 times) of the image in order to remove the background.

2D Rolling Ball - Rolls a patch from the top of a sphere (rolling ball) under every point in the image (shrunk 4 or 8 times) in order to find the background.

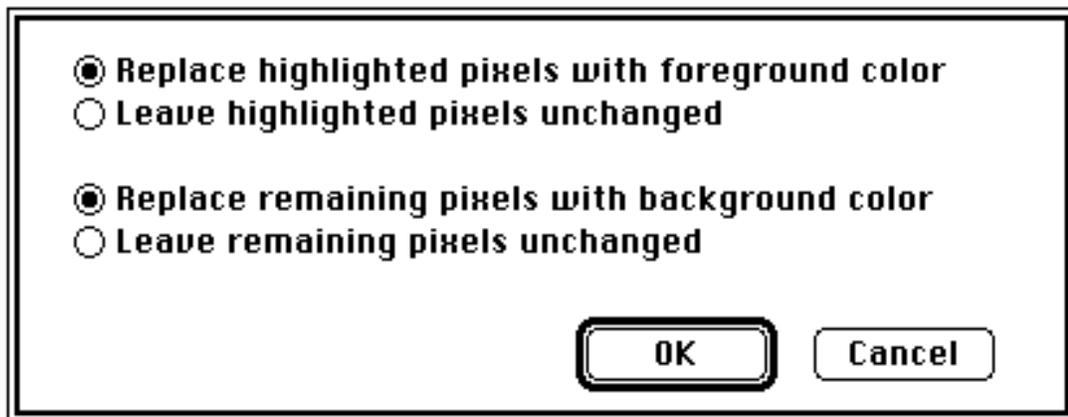
2D Remove Streaks - Gets rid of horizontal and vertical streaks as it removes background by calling 1D Horizontal and 1D Vertical consecutively.

Faster - When checked, the image is shrunk 8 times (instead of 4) for 2D rolling ball subtraction. When the ball radius is less than 15 the image is shrunk 4 times (instead of 2).

Set Radius - Allows you to set the rolling ball or disk radius. Generally, the disk/ball radius should be at least as large as the width/diameter of the largest object in the image that is not part of the background.

Apply LUT

Applies the current look-up table function to each pixel in the current selection (or of the entire image if there is no current selection) and restores the default look-up table (the identity function). This modifies the gray values so that when the image is viewed using the default grayscale look-up table it will look the same as it did before. This command provides a way of making brightness and contrast changes permanent. It can be used to posterize (reduce the number of gray values) an image by loading and applying, for example, a LUT consisting of four shades of gray. It can also be used to convert color images to grayscale, and to convert a thresholded image to binary.



If density slicing is in effect, the above dialog box is displayed, allowing you to process highlighted pixels in one way, and all other pixels another way.

Enhance Contrast

Enhances the contrast of the currently active image. A new look-up table function is generated by doing a linear histogram stretch of the current selection. Use the Apply LUT command to make the contrast change permanent. Enhance Contrast does not work with true color images.

Equalize

Performs histogram equalization based on the density histogram of the current selection. A new look-up table function is generated that more evenly distributes the gray values of the image. The newly created function is displayed in the Map window. Use Apply LUT to make the contrast change permanent. Equalization does not work with true color images.

Fix Colors

Attempts to correct color anomalies by mapping pixels with values of either 0 or 255 to the nearest matching color in the other 254 LUT entries. This usually corrects pseudo-color problems due to the way *Image* “hard wires” entries 0 and 255 to white and black respectively.

Analyze Menu

Measure

Computes the area and mean gray value of the current selection and displays the results in the Values window. In addition, you can use the Options dialog box to enable other measurements, such as perimeter. Use Undo to delete the last measurement or Delete Measurement to delete an arbitrary measurement. Only highlighted pixels are included in the computation if either density slicing or thresholding are enabled. The measurement counter is incremented by one each time you use Measure. The default maximum number of measurements is 200, but this can be increased in the Options dialog box.

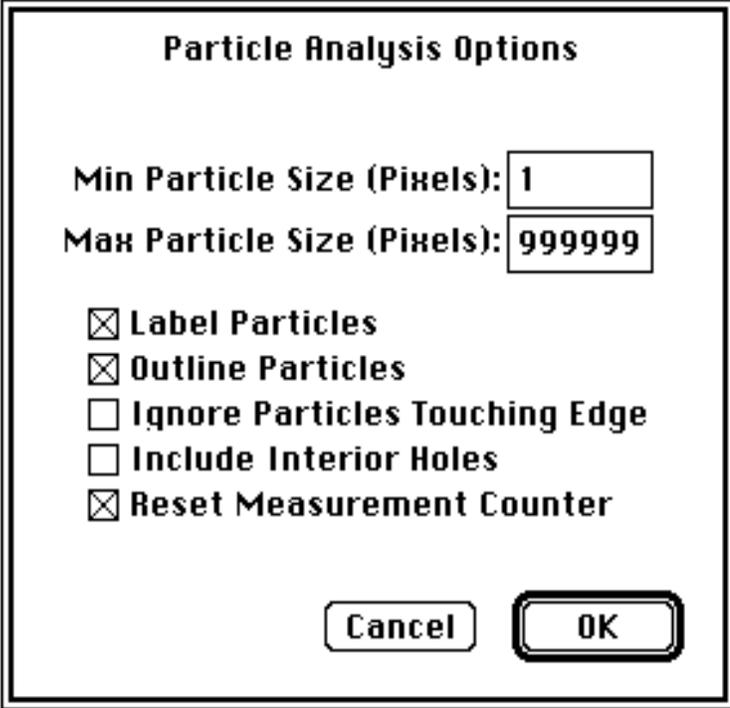
Use Show Results to display the list of measurement results, Print (with either the Values or Results window active) to print the results, Copy to copy results to the Clipboard, Export to export results to a tab-delimited (spreadsheet compatible) text file, and Reset to reset the measurement counter to zero. There is no limit to the number of measurements that can be exported, but there is a 32K byte limit when displaying, printing, or copying results.

The area of the selection will be given in calibrated units, such as square millimeters if the Set Scale command has been used to establish the spatial scale. If Calibrate has been used to perform density calibration, then gray value readings will be converted, using the standard curve generated by Calibrate, and the results reported in calibrated units, such as optical density or isotope concentration.

The most efficient way to organize measurement results is to have a spreadsheet on the screen at the same time you are using *Image*. Make a series of measurements (Command-1), Copy them to the Clipboard (Command-C), click on the spreadsheet to activate it, select the cell where you want the measurements stored, Paste the results (Command-V), click on the image window to reactivate *Image*, and finally, Reset the measurement counter (Command-3).

Analyze Particles

Analyze Particles automatically counts and measures objects in binary or thresholded images. It does this by scanning across the image until it finds the boundary of an object, outlines the object using the same outlining routine used by the wand tool, measures the object using the equivalent of the Measure command, and then redraws the object in a different gray level so that it becomes invisible to the scanning process. Use Show Results to display the recorded measurements. Up to 32767 particles can be counted, but measurement recording is limited to the first *Max Measurements* (set in the Options dialog box) particles. Hold down the option key to bypass the dialog box. Use command-period to abort particle analysis.



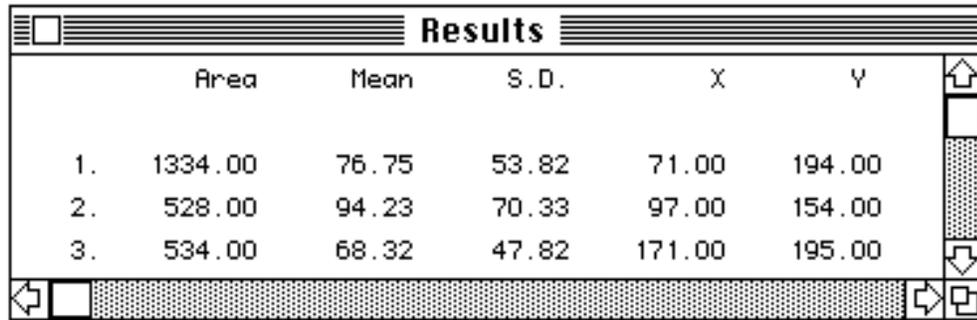
The image shows a dialog box titled "Particle Analysis Options". It contains two input fields for "Min Particle Size (Pixels)" and "Max Particle Size (Pixels)", with values "1" and "99999" respectively. Below these are five checkboxes: "Label Particles" (checked), "Outline Particles" (checked), "Ignore Particles Touching Edge" (unchecked), "Include Interior Holes" (unchecked), and "Reset Measurement Counter" (checked). At the bottom are "Cancel" and "OK" buttons.

Option	Checked
Min Particle Size (Pixels)	1
Max Particle Size (Pixels)	99999
Label Particles	<input checked="" type="checkbox"/>
Outline Particles	<input checked="" type="checkbox"/>
Ignore Particles Touching Edge	<input type="checkbox"/>
Include Interior Holes	<input type="checkbox"/>
Reset Measurement Counter	<input checked="" type="checkbox"/>

Particles smaller than *Min Particles Size* or larger than *Max Particle Size* will be ignored. Note that the sizes must be specified in pixels. Checking *Label Particles* causes Analyze Particles to draw a number, corresponding to the measurement number, on each particle found. Check *Outline Particles* if you want particles to be outlined (this currently only works for density sliced images). Checking *Ignore Particles Touching Edge* causes Analyze Particles to ignore particles touching the edge of the image. Interior holes in area and mean density computations are included if *Include Interior Holes* is checked.

Show Results

Opens a window and displays the current results table in it. If the Results window is already open, then it is activated. No more than 32K characters can be displayed in the Results window, but there is no limit to the number of measurements that can be exported to a text file.



	Area	Mean	S.D.	X	Y
1.	1334.00	76.75	53.82	71.00	194.00
2.	528.00	94.23	70.33	97.00	154.00
3.	534.00	68.32	47.82	171.00	195.00

Use the Export command (command-S when the Results window is the active) to save the measurements as a tab delimited text file that can be opened by many Mac programs, including Excel, StatView and KaleidaGraph. For correct display, it may be necessary to adjust tab settings when opening an exported file with a word processing program such as Microsoft Word. Hold down the Option key (or check *Headings* in Options) when Exporting (or Copying) results to include column and row headers. Use Print (command-P) to print the measurements, and Copy (command-C) to copy them to the Clipboard.

Show Histogram

Displays a plot showing the distribution of gray values within the selection. The plot shows, for each of the possible 256 gray values, the number of pixels in the selection that have that gray value. When the cursor is over the Histogram window, X (the gray value) and Y (the number of pixel with that gray value) are displayed dynamically in the Values window. Note that the Histogram command works with non-rectangular selections.

Using the Copy command when the histogram window is the active window will copy both the histogram plot (as a PICT) and the histogram data values (as a single column of text) to the clipboard. Histogram data values can also be saved to a text file using the Export command.

Plot Profile

Generates a density profile plot based on the current rectangular or line selection. For rectangular selections wider than they are tall (or if the Option key is down), it produces a “column average plot”, where the width of the plot is equal to the width of the selection and each point in the plot represents the average gray value of the pixels in the corresponding column in the selection. For rectangular selections higher than they are wide, it does a top to bottom “row average plot”,

where the width of the plot is equal to the height of the selection and each point in the plot is the average of the corresponding row.

For line selections, it displays a plot of the gray values along the selected line. Pixel averaging is performed when using straight line selections and the line width is greater than one. For example, assuming the maximum line width is selected by clicking on the thickest line at the bottom of the tool palette, each data point plotted is the average of eight pixels.

The Profile Plot Options command can be used to vary the way profile plots are displayed.

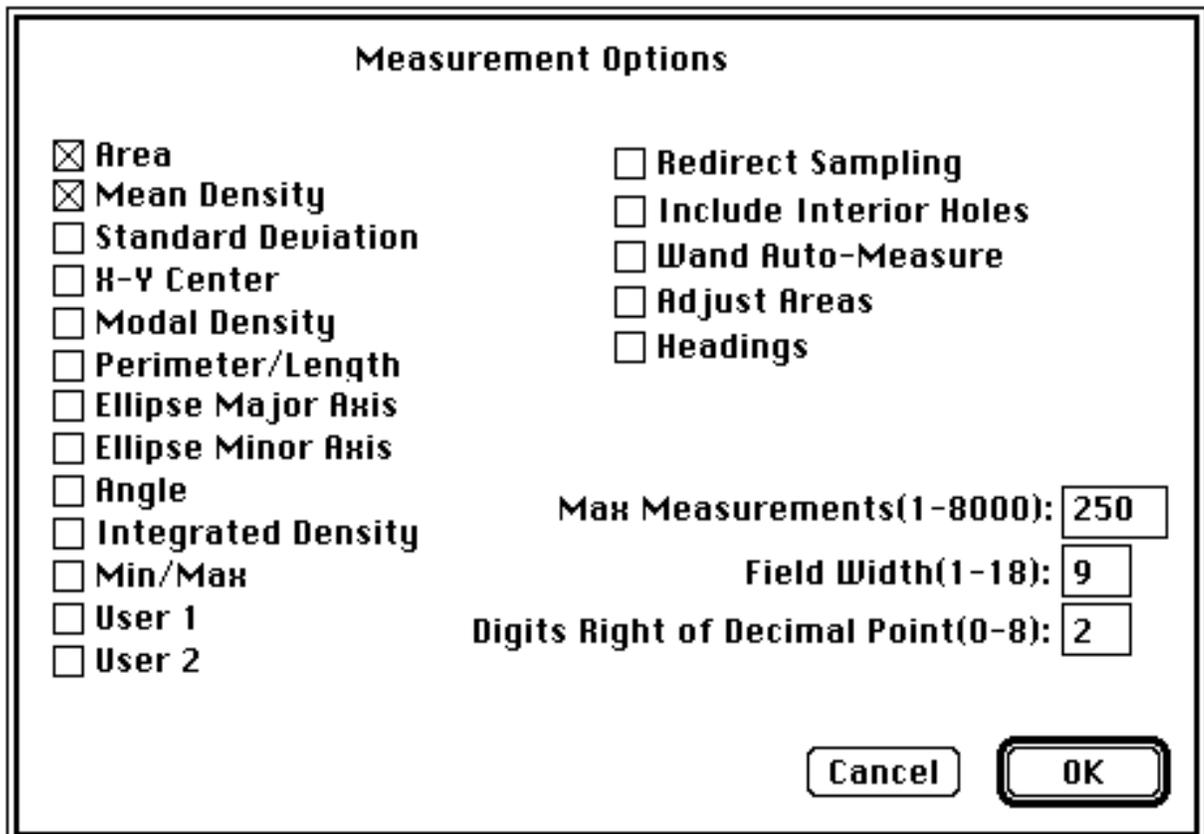
Using the Copy command when the Plot window is the active window will copy both the profile plot (as a PICT) and the data values (as a single column of text) to the clipboard. Plot values can also be saved to a text file using the Export command.

Surface Plot

Generates a surface plot of the current selection. The entire image is plotted if there is no selection. Type command-period to abort plotting. You can exaggerate the vertical scale in the plot by increasing the contrast of the image before plotting using the controls in the Map window. To improve the quality of plots of small selections, use the Scale and Rotate command to enlarge the selection before plotting, which will increase the number of lines in the plot.

Options...

The Options dialog box allows you to specify which measurements are recorded by the Measure and Analyze Particles commands and displayed by Show Results. Double-clicking on the polygon tool also brings up this dialog box.



The image shows a dialog box titled "Measurement Options". It contains a list of checkboxes for various measurements, with "Area" and "Mean Density" checked. On the right side, there are three input fields: "Max Measurements(1-8000):" with the value "250", "Field Width(1-18):" with the value "9", and "Digits Right of Decimal Point(0-8):" with the value "2". At the bottom right, there are "Cancel" and "OK" buttons.

Measurement	Checked
Area	Yes
Mean Density	Yes
Standard Deviation	No
X-Y Center	No
Modal Density	No
Perimeter/Length	No
Ellipse Major Axis	No
Ellipse Minor Axis	No
Angle	No
Integrated Density	No
Min/Max	No
User 1	No
User 2	No
Redirect Sampling	No
Include Interior Holes	No
Wand Auto-Measure	No
Adjust Areas	No
Headings	No

Max Measurements(1-8000): 250
Field Width(1-18): 9
Digits Right of Decimal Point(0-8): 2

Buttons: Cancel, OK

Area - Area of selection in pixels. Area will be given in calibrated units, such as square millimeters, if you have used the Set Scale command to do

spatial calibration.

Mean - Average gray value of the pixels within the selection. It is the sum of the gray values of all the pixels in the selection divided by the number of pixels. Given

in calibrated units (e.g. optical density) if you have used the Calibrate command to generate a standard curve.

Standard Deviation - This is the standard deviation of the gray values used to generate the mean gray value.

X-Y Center - Center of the best fitting ellipse, measured from either the upper left or lower right corner of the image, depending on the status of the *Invert Y Coordinates* check box in the Preferences dialog box. This option is automatically selected when X-Y coordinate values are recorded using the cross hair tool.

Modal Value - Most frequently occurring gray value within the selection. Corresponds to the highest peak in the histogram.

Perimeter/Length - Length around the outside of the selection, or line length for line selections. The perimeter is only computed for freehand and polygon selections, or when using Analyze Particles. This option is automatically enabled when Measuring a line selection.

Major/Minor Axis - Lengths of the major and minor axes of the best fitting ellipse.

Angle - This is the angle between the major axis and a line parallel to the x-axis of the image, or it is an angle measured using the angle tool. This option is automatically enabled when measuring angles using the angle tool.

Integrated Density - Sum of the gray values of each pixel in the selection, with background subtracted. Use to measure the size (volume) of spots or bands in electrophoresis gels. It is computed using the following formula:

$$\text{IntegratedDensity} = N * (\text{Mean} - \text{Background})$$

where N is number of pixels in the selection, and Background is the modal gray value (most common pixel value) after smoothing the histogram. Note that this formula assumes that the background is lighter (has lower pixel values) than the object being measured. The background level may be computed incorrectly if there isn't a well defined peak in the histogram. This can happen if not enough background is included within the selection or the background is not very uniform.

Min/Max - Minimum and maximum gray values within the current selection.

User 1, User 2 - Add new columns to the results table that can be used by user written macros to record and display derived results. Several example macros in the file “Measurement Macros” display results using *User 1* and *User 2*.

When *Redirect Sampling* is checked, pixel data for calculating the mean gray value is taken from the corresponding area of a second image. Requires that exactly two image windows be open, and that these two images be the same size.

The wand tool include interior holes in area and mean density computations if *Include Interior Holes* is checked. If *Wand Auto-measure* is checked, the Measure command is automatically invoked whenever an object is outlined using the wand tool. *Adjust Areas* is used by the Gel Plotting Macros to attempt to correct for the tendency of the wand tool to underestimate the size of small peaks by not counting pixels under the peak boundary. When this option is selected, the area is increased by $0.5 * \text{Perimeter} + 1.5 * \text{AspectRatio}$, where AspectRatio is the width to height ratio of the selection's bounding rectangle.

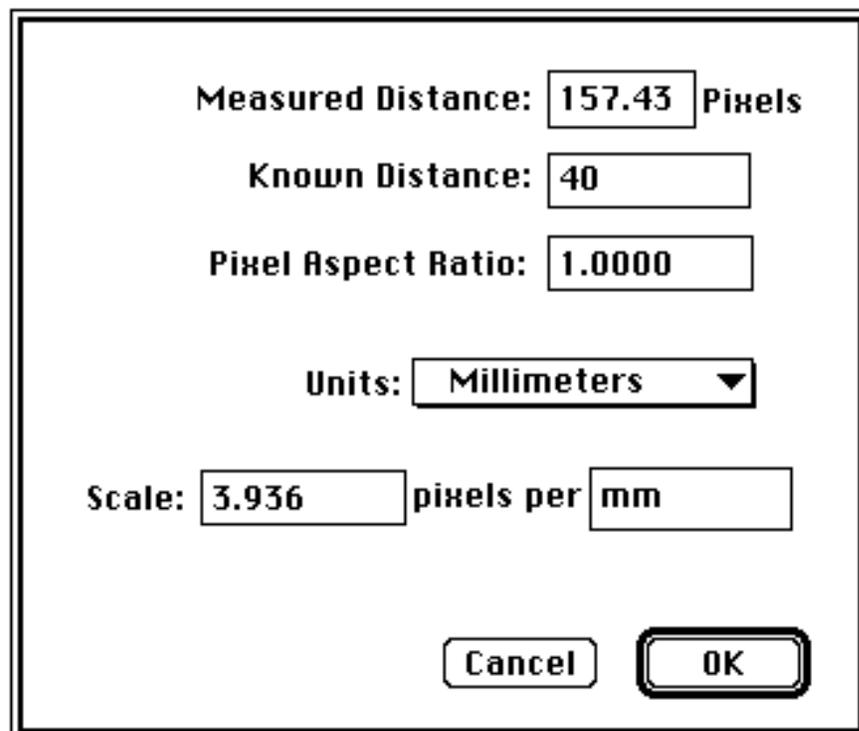
If *Headings* is checked, column and row headings will be added to results Copied to the Clipboard or Exported to a text file.

Max Measurements specifies the size of the arrays used to hold results produced by the Measurement command, by Analyze Particles, and by the angle and cross hair tools. You must Record Preferences, Quit, and restart *Image* before any change you make will take effect.

Field Width specifies the column width in characters for results displayed in the Results window, Printed, Copied to the Clipboard, or Exported. *Digits to the Right of Decimal Point* specifies the number of digits that follow the decimal point.

Set Scale...

Performs spatial calibration so that results from length and area measurements are presented in calibrated units, such as millimeters. Before setting the scale, use the line selection tool to make a straight line selection that corresponds to known distance. Then, bring up the Set Scale dialog box, select a unit of measurement from the *Units* pop-up menu, and enter the known distance in *Known Distance*.



The image shows a dialog box titled "Set Scale...". It contains several input fields and a dropdown menu. The "Measured Distance" field is set to 157.43 Pixels. The "Known Distance" field is set to 40. The "Pixel Aspect Ratio" field is set to 1.0000. The "Units" dropdown menu is set to "Millimeters". The "Scale" field is set to 3.936 pixels per mm. There are "Cancel" and "OK" buttons at the bottom right.

Measured Distance:	157.43	Pixels
Known Distance:	40	
Pixel Aspect Ratio:	1.0000	
Units:	Millimeters	▼
Scale:	3.936	pixels per mm

Setting *Pixel Aspect Ratio* to a value other than 1.0 enables support for different horizontal and vertical spatial scales, for example 100 pixels/cm horizontally and 95 pixels/cm vertically. Before setting the aspect ratio, calibrate to a known horizontal distance. Then enter the pixel aspect ratio into *Pixel Aspect Ratio*. To

find the pixel aspect ratio, measure the width and height (in pixels) of a digitized object with a known 1:1 aspect ratio. The pixel aspect ratio is computed by dividing the width by the height. Note that only the horizontal scale is shown. Divide the horizontal scale by the aspect ratio to compute the vertical scale.

Once the scale has been set you can switch to other units of measurements, for example from inches to centimeters. If you know what the scale for an image is (e.g., 300 dpi), then that value can be directly entered into *Scale* . Select *Pixels* from the pop-up menu to disable spatial calibration. To use a unit of measurement that is not predefined, select *Arbitrary Units* and manually type in the unit. Double-clicking on the line selection tool will also present the Set Scale dialog box.

Note that *Image* displays a black diamond in the title bar of images that are spatially calibrated.

Calibrate...

Allows you to calibrate to a set of density standards, such as a calibrated optical density step tablet or radioactive isotope standards. Before calibrating, you must measure the standards. To do this, first use the Reset command to set the measurement counter to zero. Then use one of the selection tools and the Measure command to record the mean gray value of each of the standards. Note that the standards must be measured in order, starting with the lowest gray value (lightest) standard. When you have finished making the measurements, use select Calibrate to display the dialog box shown below. To calibrate the image, enter the actual values in the *Known* column, select a curve fitting method, enter the unit of measurement, and click OK. If the calibration curve is not satisfactory, bring up the Calibrate dialog box again and select a different curve fitting method.

Measured		Known
1	30.30	0.060
2	38.78	0.200
3	64.65	0.340
4	93.29	0.490
5	143.57	0.640
6	202.28	0.790
7	242.92	0.940
8	255.00	1.100
9		
10		
11		
12		
13		
14		

- Straight Line
- 2nd Degree Polynomial
- 3rd Degree Polynomial
- 4th Degree Polynomial
- Exponential
- Power
- Log
- Rodbard
- Uncalibrated OD

Unit of Measure:

Copy Function to LUT

Remove Calibration

Rodbard is a four parameter general curve fit function proposed by David Rodbard at NIH. The form of the equation is: $y = (D) + (A - D) / (1 + (x/C)^B)$.

Selecting *Uncalibrated OD* causes *Image* to convert gray values to uncalibrated optical density values using the following function:

$$\text{Uncalibrated OD} = \log_{10}(255 / (255 - \text{Gray Value}))$$

You do not need to measure OD standards or enter known OD values to enable this transformation.

Pressing *Invert OD* performs the following function on the entered (known) standards:

$$\text{Inverted OD} = -\log_{10}(1.000 - 10^{(-\text{Entered OD})})$$

Optical densities are converted to transmission, subtracted from perfect transmission and converted back to OD yielding the reciprocal density. This function is of use to those who have a positive set of optical density standards but a photographic or other negative image. It is also of use to those who quantitate reflected light images but wish to specify results in terms of transmitted light. This is often the case in anatomical imaging. Entered optical densities must range from 0.00001 to 4.62.

The *Save* button allows you to save both measured and known values to a text file so they can be restored later using the *Open* button. If there are no measured values (count=0), *Open* restores both the measured and known values, otherwise, only the known values are restored.

If *Copy Function to LUT* is checked then the current calibration function will be copied to the video look-up table when you exit this dialog box. You can then use *Apply LUT* to apply the calibration function the pixel values. If *Remove Calibration* is checked then the spatial calibration, if any, associated with the currently active image will be removed.

If you hold down the Option key when invoking *Calibrate* you will be allowed to change the measured values. This feature allows you to enter measurements acquired previously or acquired from another system.

Note that *Image* displays a white diamond in the title bar of images that are density calibrated.

Redo Measurement

Allows you to repeat a previous measurement. Simply enter the number for the measurement you want to repeat and it will be replaced the next time you use the *Measure* command. Redo only works for measurements made using the *Measure* command, not for measurements made with the angle or cross hair tools.

Delete Measurement

Deletes the specified measurement and renumbers any subsequent measurements.

Reset

Resets the measurement counter to zero.

Restore Selection

Returns the previous region or line selection to its original position immediately after an operation that has removed it. If there is a selection currently active, this command restores the previous one. Can also be used to transfer a selection from one window to another.

Label Selection

Outlines the current selection in white and labels it with the measurement count. Can be used to keep track of which objects have been measured when doing redirected sampling using the Measure Redirected and Label macro.

Special Menu

Start Capturing

Continuously captures and displays TV camera images using either the Data Translation DT2255 QuickCapture or the Scion LG-3 frame grabber cards. The capture rate varies from four to eight frames per second, with 68040 based Macintoshes using built-in video providing the fastest rate. Changes to Stop Capturing while digitizing is in progress. Clicking in the Camera window with any tool except the magnifying glass or the grabber will also cause digitizing to stop. Newly created Camera windows inherit the look-up table, as well as any spatial or density calibration, of the currently active window, if there is one.

While capturing, you are allowed to change contrast, alter color schemes, zoom or pan. Histograms are continuously computed and displayed when you use the Histogram command.

Average Frames

Averages or integrates two or more video frames to reduce time-varying random noise. Averaging will be done only for the current rectangular selection, or for the entire image if there is no selection.

Number of Frames:

Video Rate Capture

Integrate

Show 16-bit Values

Fix Scale

Min:

Max:

Number of Frames is the number of frames that will be averaged or integrated. Note that there is a possibility of overflow if this value is set to more than 128 since frames are summed in a signed integer buffer with a maximum pixel value of 32,767.

Check *Video Rate Capture* to use the Scion LG-3's on-board memory to capture frames to be averaged or integrated at video rates (25 or 30 frames per second). For example, when averaging 32 frames, the frames are captured in about one second instead of 15-25 seconds. It will still take 15-25 seconds, however, to compute the average. The number of frames that can be captured depends on how much memory is installed. A 4MB LG-3 can capture 8 frames at video rates and one with 16MB can capture 32.

Check *Integrate* to sum the frames, rather than averaging them. Integration increases image quality and contrast in low light situations. Frames are summed using a 16-bit buffer and the resulting 16-bit pixel values are linearly scaled to a range of 0 to 255. Check *Show 16-bit Values* to create a calibration function that causes approximations of the integrated 16-bit values to be displayed.

If *Fix Scale* is checked then the values in *Min* and *Max* control how integrated images are linearly scaled from 16-bits to 8-bits. If it is not checked, the computed minimum and maximum values are used. The actual minimum and maximum values are always displayed in the Values menu.

You can bypass the dialog box by holding down the Option key. The Average Frames macro (in the file Video) also bypasses the dialog box, and, in addition, allows you to do averaging by simply pressing the "A" key.

Save Blank Field

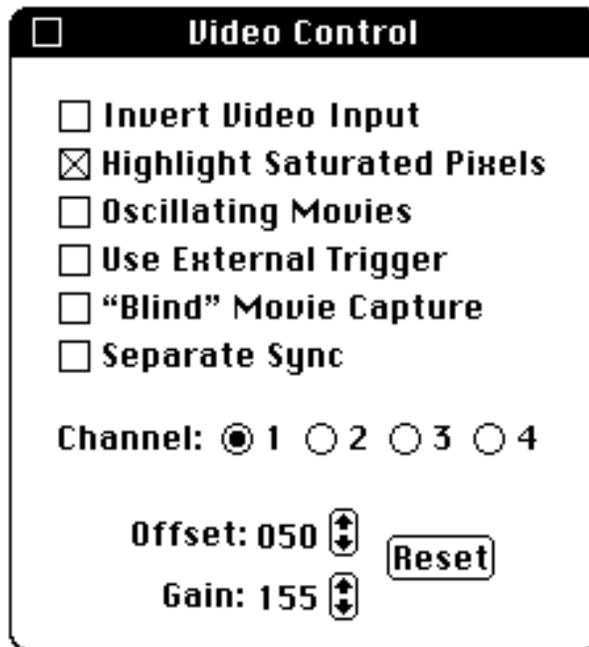
Saves a median brightness blank field which will be used to correct for uneven illumination. Before using this command, you must Start Capturing and adjust the lens diaphragm and/or lightbox intensity so that the average pixel value, as shown by the dynamic pixel value displayed in the Values window, is approximately 128.

The Stop Capturing command will use the reference image previously acquired by Save Blank Field to correct shading errors in the newly acquired image. It does this by dividing each pixel in the newly acquired image by a correction factor computed for each of the 300,000 pixels in the blank field. This correction factor is generated by dividing each gray value in the blank field by the mean gray value.

You can digitize a single frame without shading correction by holding down the Option key while selecting Stop Capturing. Close the "Blank Field" window if you want to stop doing shading correction.

Video Control...

Displays a modeless dialog box that allows you to interactively control video capturing and to alter the behavior of the Animate and Make Movie commands.



Images acquired using a frame grabber card are inverted if *Invert Video Input* is checked.

Checking *Highlight Saturated Pixels* enables a feature that, during live capture, causes all pixels that over saturate the camera (are too bright) to be displayed in red and all pixels that under saturate the camera (are too dark) to be displayed in yellow.

Check *Oscillating Movies* if you want movies to run in a auto-reversing mode (1234321234), as opposed to the default wrap-around mode (123412341234).

Use External Trigger enables support for the external trigger feature of the Data Translation QuickCapture and Scion LG-3 when using the Start Capturing, Average Frames or Make Movie commands. External trigger events are signaled by a 5 volt falling TTL edge on input line 7 of the QuickCapture cable.

Checking *Blind Movie Capture* disables screen updates when using the Make Movie command, allowing faster frame capture rates.

Check *Separate Sync* when using the Scion LG-3 frame grabber and an RGB color camera with separate composite sync output.

Channel allows you to specify which of four input channels is used by the QuickCapture or Scion frame grabber cards. With the QuickCapture card, the

input cable labeled “0” is used for channel 1.

Offset and *Gain* allow you to adjust the A/D offset (brightness) and gain (contrast) of the Scion LG-3 frame grabber. Changes are interactively displayed in live video mode. The objective when using these controls is to optimize the image brightness and contrast. One way to do this is to enable *Highlight Saturated Pixels* and interactively adjust offset and gain to just eliminate the saturated pixels within the region of interest. Another way is to

display the histogram and interactively adjust offset and gain to spread out the histogram as much as possible.

Several command key shortcuts are useful in conjunction with this dialog box. Command-W closes the Video Control dialog box. Command-G enables or disables live video capture. Command-H displays a histogram, continuously updated during live video. If it is active, Command-W closes the histogram window.

Photo Mode

Erases the entire screen to the current background color and then redraws the current image window without the menu bar, title bar, tool palette, etc. Before selecting Photo Mode, you can change the background color by clicking in the LUT window with the eraser tool. Holding down the Option key while selecting Photo Mode causes the image to be drawn starting at the top of the screen using the space formally occupied by the Menu Bar.

Load Macros...

Opens a text file containing one or more macros written in Image's Pascal-like macro programming language. Each macro in the file causes a new command to be inserted at the bottom of the Special Menu. Macros may be assigned to any key, including function keys on the extended keyboard. For example, a macro named "Test Macro [T]" would be assigned to the 'T' key, and one named "Another Macro [F1]" would be assigned to the F1 function key. In both cases, it is not necessary to hold down the command key. Macros can be aborted by typing command-period. When launched, *Image* automatically loads the macros contained in the file "Image Macros", as long as this file is in the same folder as *Image*, or in the System Folder.

Example macros for performing the following functions, and many others, are distributed with *Image*: plotting gel lanes; drawing arrows; generating a sine wave; creating a grayscale step function; printing all currently open images; generating bas-reliefs; clearing outside of the current selection; plotting XYZ coordinate data; importing FITS files; recovering X-Y coordinate data from line plots; and generating an ASCII dump.

The macro programming language is documented in Appendix A.

Stacks Menu

The commands in this menu create or operate on stacks, which are three dimensional images consisting of two or more

“slices”. The slices can be consecutive serial sections in a 3D data set, frames in a movie loop, red, green and blue (RGB) channels of a 24-bit color image, or any related set of images. The ‘<’ and ‘>’ keys are used to move through the slices in a stack. The current slice and total number of slices are displayed in parentheses in the title bar. Stacks are displayed in a single window and can be saved to a single disk file using the Save, Save As or Export commands. Most commands in *Image*, with the exception of Save, Save As, Export and Open, operate only on the current slice. Several example macros (in the file “Stacks”) are available that operate on all the slices in a stack

Windows to Stack

Converts the set of images currently being displayed in separate windows to a stack. The images must all be the same size. A macro, also called “Window to Stack”, is available that works with windows that are not all the same size.

Stack to Windows

Converts the currently active stack to windows. A stack with 20 slices would be converted to 20 normal image windows.

Add Slice

Adds a new blank slice to the stack following the currently displayed slice.

Delete Slice

Deletes the currently displayed slice. Undo will restore the last slice deleted.

Next Slice

Displays the slice following the currently displayed slice. Note that is not necessary to hold down the command key to use the keyboard shortcut, i.e., you only need to press the '>' key. You can also use the Page Down key on extended keyboards.

Last Slice

Displays the slice before the currently displayed slice. As a shortcut, use the '<' or Page Up keys.

Make Movie...

Captures a series of video frames into a stack. *Image* creates a stack the same width and height as the current selection and large enough to hold the number of frames specified. You will be asked to enter the time to delay between frames. Entering zero results in the fastest possible sampling rate. As shown in the table below, the delay time is the inverse of frames per second (fps). For example, to capture at two fps, you would enter a delay of .5. After *Image* has completed recording the movie it will compute the actual frame rate and display it in the Values window. If the computed rate is not the same as the desired rate then the frames were probably captured at uneven intervals. If an even sampling rate is required, you should specify a slower rate, use a smaller selection, or try enabling "Blind" Capture in the Video Control dialog box. Type command-period to abort the movie making process.

The following table assumes a 60Hz frame grabber card that captures at a maximum rate of 30 fps, or .033 seconds per frame. A 50Hz (PAL) card captures at a maximum rate of 25 fps, or 0.04 seconds per frame. For 50Hz cards, the time delay should be a multiple of .04, the time needed to capture one frame. For example, specify a delay of .08 to capture 12.5 fps (every other frame) or .2 to capture 5 fps (every fifth frame).

Time Delay

FPS

Maximum Size

.067	15	128 X 128
.1	10	200 X 200
.133	7.5	300 X 300
.2	5	400 X 400
.333	3	640 X 480
.5	2	640 X 480

Capture Frames

Captures a frame and adds it to a stack each time the mouse button is pressed.
Press any key to stop capturing.

Animate

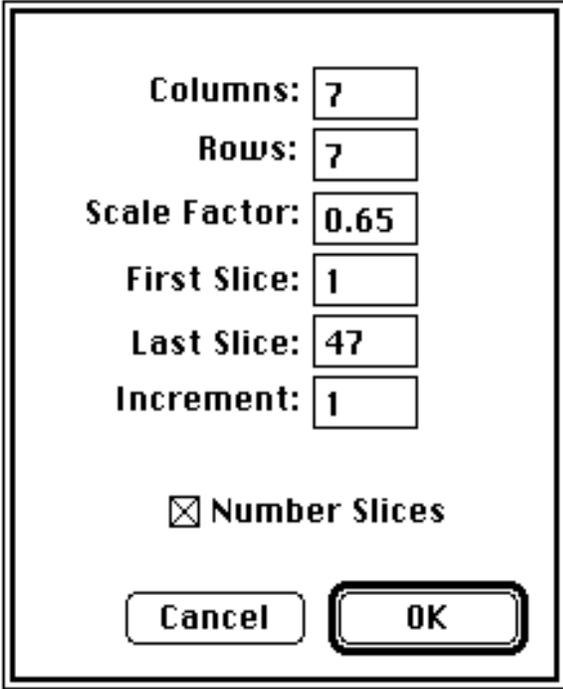
Animates the current stack by repeatedly displaying its slices (frames) in sequence. Holding the Option key down causes the screen to be erased to the current background color before the animation starts (or type command-option-‘=’ as a shortcut). The animation speed is controlled by pressing keys ‘1’ through ‘9’. 68040 based Macintoshes using built-in video provide the fastest and smoothest animation. The right and left arrow keys can be used to single step through the slices. Press the mouse button to stop the animation. Check *Oscillating Movies* in the Video Control dialog box to get *Image* to automatically reverse direction at the beginning end of the frame sequence.

Average

Creates a new image that is the arithmetic average of all the slices in the current stack.

Make Montage...

Creates a new composite image from the slices in the current stack.



Columns: 7
Rows: 7
Scale Factor: 0.65
First Slice: 1
Last Slice: 47
Increment: 1

Number Slices

Cancel OK

Columns and *Rows* control the number of columns and rows used in the composite image. *Scale Factor* determines how the slices in the stack are scaled when they are copied to the composite image. Decreasing the scale factor makes the composite image smaller and reduces the amount of memory required. *First Slice* and *Last Slice* specify which slices in the stack get copied to the composite image. Every slice (starting at *First Slice*) is copied if *Increment* is set to one, every other slice if it is set to two, every third slice if it is set to three, etc. Check *Number Slices* to have the slices in the composite image labeled with the slice

number. Use the Font, Size and Style commands in the Options menu (before using Make Montage) to vary the format of the labels.

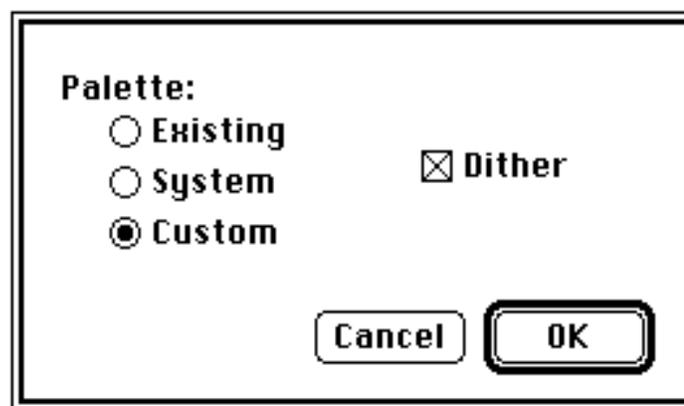
Capture Color

Captures and displays a 24-bit RGB color image. Requires either the Scion LG-3 or data Translation QuickCapture frame grabber card and an RGB color camera with separate composite sync output. With the Scion LG-3, the optional four channel cable (CRGB-LG3) is required and *Separate Sync* must be checked in the Video Control dialog box.

With the Data Translation QuickCapture, the W5 jumper must be installed and the red, green, blue and sync camera outputs connected to cables 1, 0, 2 and 4 respectively. Color capture requires System 7 and is very memory intensive.

RGB to 8-bit Color...

Converts an RGB color image (in the form of a three slice stack) to 8-bit indexed color. You have a choice of three 256 color look-up tables to use with the indexed color image. Select *Existing* to use the current look-up table. Select *System* to use the Apple default 8-bit color table. Select *Custom* to create a custom 256 color table based on the colors in the RGB image.



Checking *Dither* causes the 8-bit color image to be drawn using error diffusion dithering, a technique that mixes existing colors to create the illusion of additional colors. Dithering will usually eliminate color banding in the 8-bit image.

8-bit Color to RGB

Converts an 8-bit indexed color image into a three slice (red, green and blue) stack, a format that allows filter operations such as smoothing and sharpening to be performed. Macros are available in the file "Stacks" for automating filtering operations on RGB stacks.

RGB to HSV

Converts an RGB color image (in the form of a three slice stack) to HSV (Hue, Saturation and Value).

Project...

Generates an animation sequence by projecting through a rotating 3D data set onto a plane. Each frame in the animation sequence is the result of projecting from a different viewing angle. To visualize this, imagine a field of parallel rays passing through a volume containing one or more solid objects and striking a screen oriented normal to the directions of the rays. Each ray projects a value onto the screen, or projection plane, based on the values of points along its path. Three methods are available for calculating the projections onto this plane: nearest-point, brightest-point, and mean-value. The choice of projection method and the settings of various visualization parameters determine how both surface and interior structures will appear. This routine was written by Michael Castle (e-mail: mike.castle@med.umich.edu) and Janice Keller of the University of Michigan Mental Health Research Institute (MHRI).

Distance Between Slices:	<input type="text" value="1.0"/>
Initial Angle(0-359°):	<input type="text" value="0"/>
Total Rotation(0-360°):	<input type="text" value="360"/>
Rotation Angle Increment:	<input type="text" value="10"/>
Lower Transparency Bound:	<input type="text" value="0"/>
Upper Transparency Bound:	<input type="text" value="254"/>
Surface Opacity (0-100):	<input type="text" value="0"/>
Surface Depth-Cueing (0-100):	<input type="text" value="100"/>
Interior Depth-Cueing (0-100):	<input type="text" value="0"/>

Save Projections to Disk
 Minimize Window Size

Axis of rotation:	Projection Method:
<input type="radio"/> H-Axis	<input checked="" type="radio"/> Nearest Point
<input checked="" type="radio"/> Y-Axis	<input type="radio"/> Brightest Point
<input type="radio"/> Z-Axis	<input type="radio"/> Mean Value

Distance Between Slices is the interval, in pixels, between the slices that make up the volume. *Image* projects the volume onto the viewing plane at each *Rotation Angle Increment*, beginning with the volume rotated by *Initial Angle* and ending once the volume has been rotated by *Total Rotation*.

The *Lower and Upper Transparency Bound* parameters determine the transparency of structures in the volume. Projection calculations disregard points having values less than the lower threshold or greater than the upper threshold. Setting these thresholds permits making background points (those not belonging to any structure) invisible. By setting appropriate thresholds, you can strip away layers having reasonably uniform and unique

intensity values and highlight (or make invisible) inner structures. Note that you can use density slicing to set the transparency bounds.

Sometimes, the location of structures with respect to other structures in a volume is not clear. The *Surface Opacity* parameter permits the display of weighted combinations of nearest-point projection with either of the other two methods, often giving the observer the ability to view inner structures through translucent outer surfaces. To enable this feature, set *Surface Opacity* to a value greater than zero and select either *Mean Value* or *Brightest Point* projection.

Depth cues can contribute to the three-dimensional quality of projection images by giving perspective to projected structures. The depth-cueing parameters determine whether projected points originating near the viewer appear brighter, while points further away are dimmed linearly with distance. The trade-off for this increased realism is that data points shown in a depth-cued image no longer possess accurate densitometric values. Two kinds of depth-cueing are available: *Surface Depth-Cueing* and *Interior Depth-Cueing*. *Surface Depth-Cueing* works only on nearest-point projections and the nearest-point component of other projections with opacity turned on. *Interior Depth-Cueing* works only on brightest-point projections. For both kinds, depth-cueing is turned off when set to zero (i.e. 100% of intensity in back to 100% of intensity in front) and is on when set at $0 < n \leq 100$ (i.e. $(100-n)\%$ of intensity in back to 100% intensity in front). Having independent depth-cueing for surface (nearest-point) and interior (brightest-point) allows for more visualization possibilities.

The *Minimize Window Size* option allows you to save memory by making projection windows as small as possible given the size of the volume and the axis of rotation. If this box is not checked, projection windows for a given set of slices will be the same size regardless of the axis of rotation (convenient for animation sequences using multiple axes of rotation).

Select *Nearest Point* projection to produce an image of the surfaces visible from the current viewing angle. At each point in the projection plane, a ray passes normal to the plane through the volume. The value of the nearest non transparent point which the ray encounters is stored in the projection image. *Brightest Point* projection examines points along the rays, projecting the brightest point encountered along each ray. This will display the brightest objects, such as bone in a CT (computed tomographic) study. *Mean Value* projection, a modification of brightest-point projection, sums the values of all transparent points along each ray and projects their mean value. It produces images with softer edges and lower contrast, but can be useful when attempting to visualize objects contained within a structure of greater brightness (e.g. a skull).

Several macros (in the file “Stacks”) are available for performing various

operations on the slices making up a volume prior to using the Project command. Use “Smooth” to reduce noise in a volume. Since the projection routine assumes volumes contain one or more objects within a black background, use “Invert” to invert volumes with a white background. For low contrast volumes, increase the contrast using the controls in the Map window and then apply the look-up table to the volume using the “Apply LUT” macro. The “Remove 0 and 255” macro changes pixel values of 0 and 255 to 1 and 254 respectively. This is sometimes useful when pseudocoloring projections. Use “Replicate Slices” to eliminate the gaps seen in projections of volumes with a slice interval greater than one by increasing the number of slices. The “Make Cone” macro creates a 64^3 volume containing a cone with two rods inside that is very useful for understanding the effect of various projection parameters.

Reslice

Reconstructs a 2D image from the image volume contained in the current stack. Use the straight line selection tool to select where the reconstruction will be done. You will be prompted for the slice spacing (displacement between slices in the stack) in pixels if this information has not been previously entered. For experimenting with the Reslice command, a sample MRI volume consisting of 27 5mm slices is available via anonymous ftp from [zippy.nimh.nih.gov](ftp://zippy.nimh.nih.gov), in the directory `/pub/image/stacks`. Macros are available (in the file “Stacks”) for repetitive reslicing of image volumes, for example, to generate a set of coronal slices from an MRI volume consisting of sagittal slices.

Options

Allows you to change the slice spacing parameter, which is used by the Project and Reslice commands.

Windows Menu

Next Window

Deactivates the current image window and activates the next image in the image list, as shown at the bottom of the Windows Menu.

Stack Windows

Expands all the image windows to their original size and redraws them slightly offset from each other. If you hold down the Option key, all windows will be drawn in the same location, at the upper left corner of the screen, next to the tool palette.

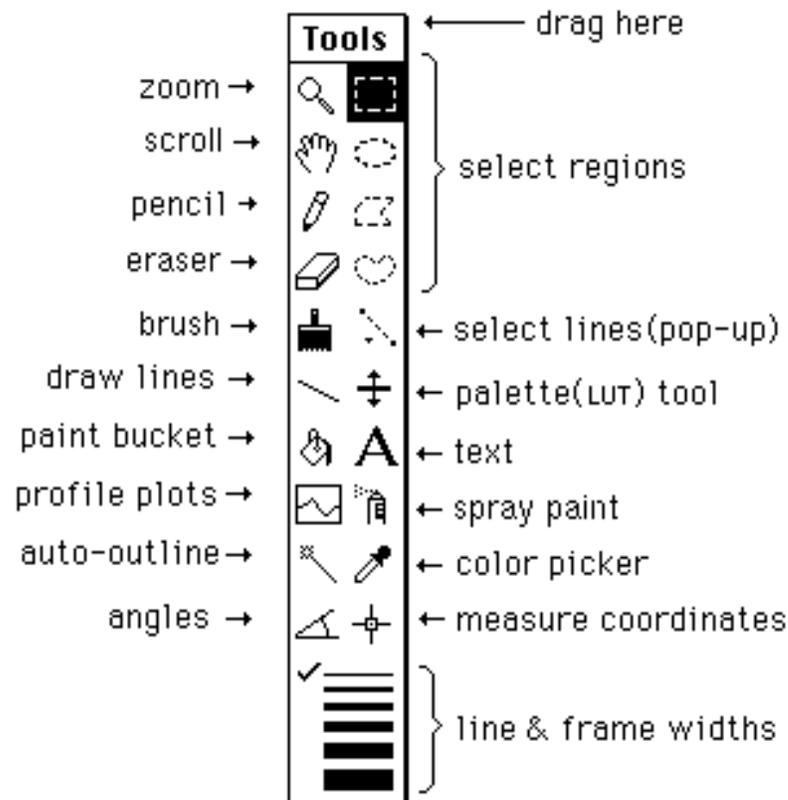
Tile Windows

Shrinks all the images windows and repositions them so that they will fit on the screen without overlapping. Hold down the Option key to draw the tiled windows in “Scale to Fit” mode. Click on the “Zoom Box” of a tiled window to expand it to fill the screen.

Image supports “synchronized scrolling” of tiled windows. To try this out, open two or more windows (they must be the same size), tile them using Tile Windows, zoom in on one of them, then pan one of the images with the option key down. Notice how all the other images zoom and pan to the same relative location.

TOOLS

The window containing the tool palette, as well as all other windows displayed by *Image* can be freely moved around the screen. All the tools work with images at any of the eight available levels of magnification. One of the tools (the line selection tool) has a pop-up menu.



Magnifying Glass - Click within the active image window to zoom. Double-click on the magnifying glass to revert to 1:1 magnification.

Option-click (or use Undo) within the image to reduce magnification in steps. Notice how the plus sign changes to a minus sign when you hold the Option key down. Eight magnification levels are available: 1:1, 2:1, 3:1, 4:1, 8:1, 16:1, 32:1 and 64:1.



Scrolling Tool (Grabber) - Moves images within windows. When using other tools (except the text tool), you can temporarily switch to the grabber by holding down the space bar.



Selection Rectangle - Use this tool to specify a rectangular subregion for use by commands in the Edit, Functions and Analysis menus. The contents of a rectangular selection can be Saved, Copied, Cleared, Filled, Duplicated, Scaled, Flipped, Rotated, Inverted, filtered, or Measured. Hold down the Shift key to constrain the selection to be square. Double-click on this tool to select the entire image. As the rectangle is being drawn, its width and height are shown in the Values window.



Oval, Polygon, Freehand - Use these tools for defining non-rectangular subregions for use by various commands in the Edit, Functions and Analysis menus. Regions defined by these tools, along with the rectangle tool, can be Copied, Filled, Cleared, Inverted, Framed, filtered, or Measured. The Fill command allows you to change colors after a region has been filled by clicking in the LUT window. Similarly, Draw Boundary allows you to change the line width by clicking on the lines in the Tools window. Double-click on the polygon tool to bring up the Measurement Options dialog box and on the freehand tool to bring up the Calibrate dialog box.

Selections can be edited by holding down the Control key to add a new selection to an existing selection or the Option key to subtract a new selection from the existing selection. When using the polygon or freehand tools, you can use the Shift key to add to the current selection. Use the arrow keys to “nudge” selections one pixel at a time.

1.4.2

Line Selection Tools - Use these tools to create straight, freehand or segmented line selections. A pop-up menu (note the little triangle) is used to select one of three line types. The pop-up menu is accessed by clicking on the tool icon and holding the mouse button down for at least 1/2 second. Once you have created a line selection, you can measure its length using the Measure command, draw it using the Fill command, generate density profile plots using the Plot Profile command, and outline the line (assuming line width is greater than one) using the Draw Boundary command. With straight lines only, you can also dynamically vary the line width by clicking on the lines at the bottom of the tool palette.

Freehand line selections are created in the same way as freehand region selections, except they are not required to be closed. Segmented line selections are created using a technique similar to the way polygon region selections are made, using a double-click to terminate the line.

Line width is specified by clicking on the lines at the bottom of the tool palette. Straight lines can be constrained to be either vertical or horizontal by holding down the Shift key. Line lengths recorded using the Measure command are given in pixels unless Set Scale has been used to perform spatial calibration. Type Command-F (Fill) and Command-1 (Measure) to quickly draw and measure the length of a line selection. Use Show Results to display the list of length measurements. Option-click with the text tool to label lines with the measured length. Double-click on the line selection tool to bring up the Set Scale dialog box.

Line selection can be moved in the same way as region of interest selections by clicking inside the “marching ants” and dragging, although this has to be done carefully for one pixel wide lines. Lines selections can also “nudged” a pixel at a time using the arrow keys. Straight line selections have three “handles” drawn as small squares. The two at either end swing and stretch the line and the one in the center is used to move the selection without changing its orientation.

Line selections can be edited in the same way as region selections by holding down the Control key to add a new selection or the Option key to subtract a new selection. Line selections, however, cannot be added or subtracted from previous selections. Once they have been edited, line selections revert to ordinary region of interest selections.



Pencil - Draws one pixel wide lines in the current foreground color. Option-click to pick up the color under the pencil. It is not necessary to hold down the Option key to pick up colors from the LUT window. Holding down the Shift key causes pencil movements to be constrained to be either horizontal or vertical.



Eraser - Erases to the current background color. Holding down the Shift key causes eraser movements to be constrained to be either horizontal or vertical. Click in the LUT window, or option-click in the image, to change the background color. The color of the eraser indicates the current background color. The background color is used by the Cut, Clear and Photo Mode commands, and as the background color for text. As a shortcut, you can double-click on the eraser to erase the entire active image.



Paint Brush - Draws in the current foreground

color. Holding down the Shift key causes brush movements to be constrained to be either horizontal or vertical. Click in the LUT window, or option-click in the image, to change the foreground color. The color of the brush indicates the current foreground color. Double-click on the brush to change its size.



LUT Tool - Click and drag in the LUT window with this tool to dynamically modify the current color look-up table. Hold the Option key down to rotate all 256 entries in the LUT. The LUT tool is also used to manipulate the density slice when density slicing is enabled. As a shortcut, you can double-click on this tool to enable/disable density slicing.



Spray Can Tool - Sprays random pixels in the current foreground color onto the active image. Double-click on the tool to change the brush diameter.



Line Drawing Tool

Draws straight lines using the current foreground color and line width. The line width is specified by clicking on the lines at the bottom of the tool palette. Lines can be constrained to be either vertical or horizontal by holding down the Shift key.



Automatic Outlining Tool (Wand)

Traces the edge of a binary, density sliced, or thresholded object and, optionally, measures and/or numbers it, producing a selection outline in the process. To outline an object, either click inside near the right edge, or outside to the left of the object. To visualize what's happening, imagine a turtle that starts moving to the right from where you click looking for a binary edge. Once it finds an edge, it follows it in a counter clock-wise direction until it returns to the point where it first found the edge.

Selections created with the wand tool are added to any existing selection if either the Shift or Control keys are held down and subtracted from any existing selection if the Option key is

held down.

You can specify that the objects be automatically measured by checking *Wand Auto-Measure* in the Analyze/Options dialog box. Objects that have been measured will also be

numbered if *Label Particles* is checked. The numbers correspond to measurement numbers. Undo can be used to remove the most recent label, along with the corresponding measurement.



Density Profile Tool

Creates a straight line selection and uses this selection to generate a density profile plot. You generate this line in the same way you use the line drawing tool to draw lines. You can use the Draw Boundary command (command-B) to draw a reference line. Averaging will be performed if the current line width is greater than one. For example, assume the maximum line width is selected by clicking on the thickest line at the bottom of the tool palette, then each data point plotted is the average of eight pixels. The line selection can be constrained to horizontal or vertical by holding down the Shift key. To highlight the pixels used to generate the profile plot, hold down the mouse button and drag in the Plot window. The Plot window, unlike the Histogram window, may be resized.

Plots can be copied to the Clipboard and then pasted into an image window. In addition to the plot, the Copy command also copies the plot data values to the Clipboard as a single column of numbers. These numbers can then be pasted into analysis and plotting programs, such as Excel and KaleidaGraph. Profile plot data values can also be exported to a text file using the Export command.

Various aspects of the plots produced by the profile plotting tool can be altered using the Profile Plot Options dialog box. As a shortcut, you can bring up this dialog box by double-clicking on the profile plotting tool.



Paint Bucket

This is a MacPaint-like Paint Bucket tool. It causes all pixels located where paint can leak from the starting point (the end of the paint coming from the bucket) to be changed to the foreground color.

A

Text Tool

Use this tool to add text to images using a typeface and style chosen from the Font, Size and Style sub-menus in the Options menu.

Various attributes, such as typeface, size and color, can be changed after the text has been entered. Once another tool has been chosen, however, or you have typed Return, the text becomes part of the image's bitmap.

Hold down the Option key and the text tool automatically types in the most recent length, angle, or area measurement. Clicking repeatedly with the Option key down enters multiple readings, starting with the most recent one. Select Show Results to reset the measurement pointer, allowing you to display a set of measurements a second time.



Eyedropper - Sets the foreground color by picking up colors from the image or from the LUT window. Option-click to change the background color. If you are using pseudocolor, double-clicking on a color in the LUT window causes the Color Picker dialog box to be displayed, allowing you to modify that color. In density slicing mode, double-clicking in the LUT window allows you to change the density slice color. Note that pixel values are displayed in the Values window as RGB components when the eyedropper tool is in use.

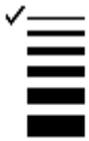


Angle Tool - Measures the angle formed by two lines drawn through a point. The angle is displayed interactively in the Values window as the lines are drawn. Use Show Results to display the complete list of angle measurements. The angle tool creates a line selection that can be used to draw the angle using the Draw Boundary command. The value of the angle can be permanently displayed in the image by option-clicking with the text tool.



Cross Hair Tool - Counts objects and records their X-Y coordinates, leaving markers so objects are not counted twice. Markers are drawn in the current foreground color and their size is related to the current line width. Holding down various modifier keys alters the behavior of the cross hair tool. Use the Option key to label using the current measurement count. Use the Control key to display X-Y coordinates. Use the Shift key to decrement the count and leave a marker in the background color. Use the Font, Size and Style sub-menus in the Options menu to vary typeface, size, etc. Use

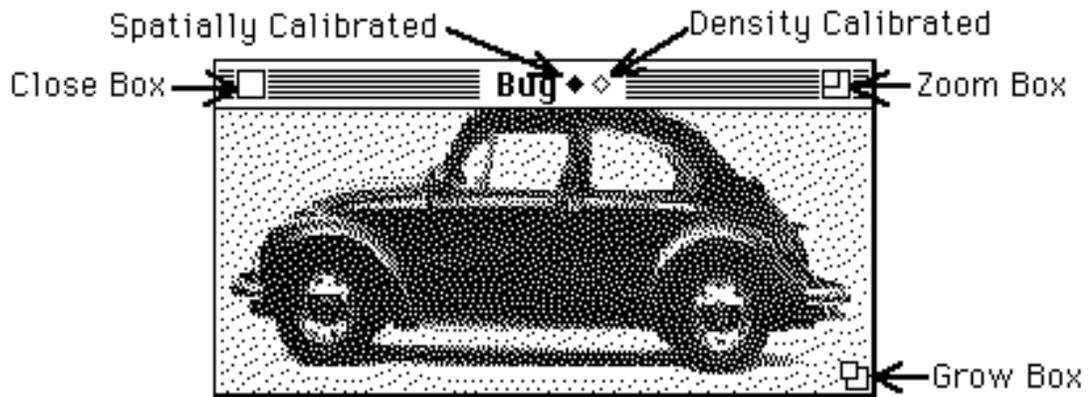
the Show Results command to display the list of X-Y coordinates. The cross hair tool always marks up the image in one way or another. To avoid this, duplicate the image and work on a copy.



Line Width - Allows you to vary the line width used by the line selection tool, the line drawing tool, the profile plotting tool, or the Draw Boundary command. The lines are 1, 2, 3, 4, 6, or 8 pixels wide. Line widths greater than eight can be specified in the Profile Plot Options dialog box.

WINDOWS

Image Windows



Images are displayed in windows such as the one above. Image windows are created when you use the New, Open, Import or Duplicate commands. Clicking in the Close Box of an image window closes the window and frees the memory used to store the image. Hold down the Option key when clicking in the Close Box to close all image windows.

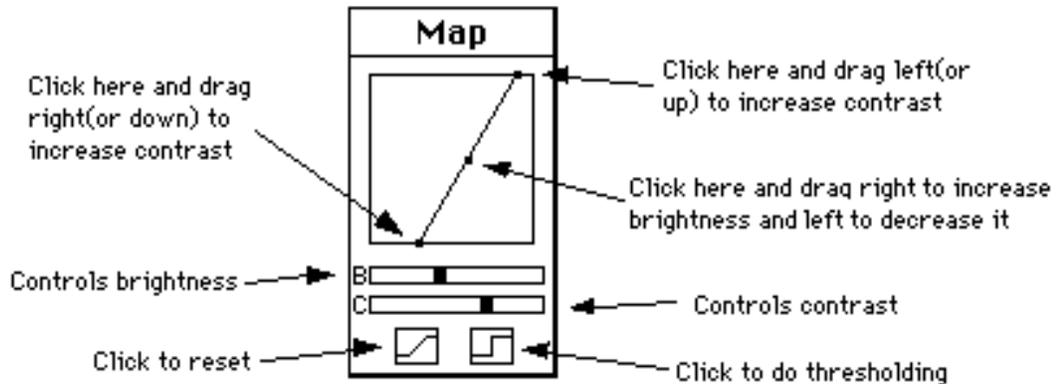
Clicking in the Zoom Box switches the window to “Scale to Fit Window” mode and resizes the window to make it as large as possible, while still maintaining the same aspect ratio. You can restore the window to its original size by clicking again in the Zoom Box, or by using Unzoom. Note that the magnifying glass and the grabber tools do not work in Scale to Fit mode.

The Grow Box is used for resizing the window. In Scale to Fit mode, the image will be rescaled to fit any resized window. You can use the Grow Box to make the window larger than its original size if you have zoomed the image using the magnifying glass.

A black diamond is displayed in the title bar of spatially calibrated images and a white diamond if the image is density

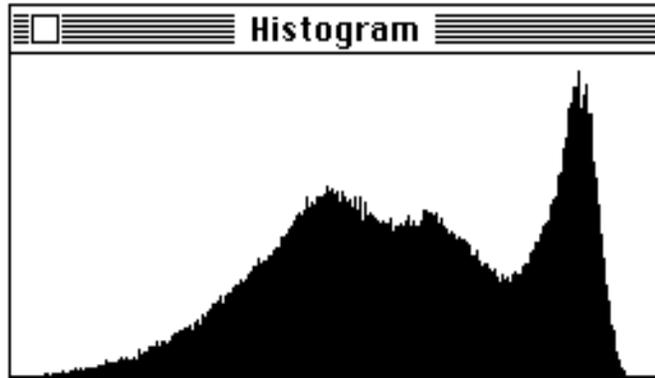
calibrated.

Map



The Map window allows you to vary the brightness and contrast of images by modifying the active video look-up table. To vary brightness, click and drag inside the frame. This moves the plot (a piece-wise linear transformation function) horizontally, changing the Y-intercept while maintaining a fixed slope. Brightness can also be altered using the 'B' slide control. To change contrast, click and drag in the margin to move the two end-points that define the function, or use the 'C' slide control. A good strategy for optimizing the contrast of an image is to click (outside the frame) in the lower left hand corner, than drag horizontally to the right until the image starts to saturate. Similarly, click in the upper right hand corner, and drag horizontally to the left.

Histogram



The Histogram window displays the gray value histogram produced by the Show Histogram command. This function shows, for each of the 256 possible gray values, the number of pixels within the selection that have that gray value. The actual histogram values are dynamically displayed in the Values window whenever the cursor is over the histogram window. Both the histogram plot and the 256 data values can be copied to the clipboard (using Copy) whenever the histogram window is active. The data values can also be saved to a text file using the Export command.

Another way to display histograms is to use the macro distributed with *Image* (in “More Macros”) that displays histograms in grayscale or color, where each of the 256 columns is drawn in the grayscale or color that that column represents.

LUT

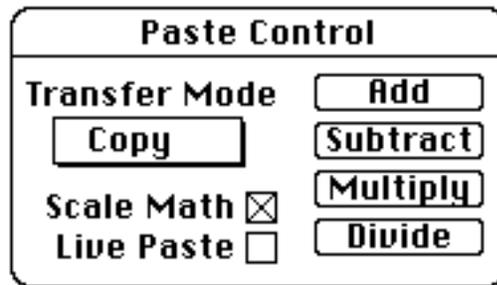


This window displays the contents of the video Look-Up Table (LUT), which is used to transform each of the 256 possible pixels values into one of 16 million possible screen colors.

Click in the LUT window with any of the drawing tools to pick up a new drawing (foreground) color. Click in the LUT window with the eraser, or option-click with any other tool, to pick up a new background color. The Save As command can be used to save look-up tables separately from images.

With the LUT tool (the one with double-headed arrow), click and drag near the top or bottom of a color table to stretch it. Click and drag near the center to move it up or down. To edit a color in a color table, double-click on it with the eyedropper tool. All 256 entries in the LUT can be rotated by clicking and dragging with the Option key held down.

Paste Control



The Paste Control window allows you to control how image selections are pasted, or to do image arithmetic on pasted images. It is only effective during paste operations. Use the *Transfer Mode* pop-up menu to specify the method (*Copy*, *And*, *Or*, *Xor*, *Replace*, or *Blend*) used to copy the image during a paste operation. The Paste Control window is activated by selecting Paste Control from the Windows menu, or by typing Command-Y.

In the default *Copy* mode, pasting occurs normally. When *And*, *Or*, or *Replace* are selected, the selection is copied to the screen using “And”, “Or”, or “Replace with Transparency” modes, respectively, allowing you to see both the object being pasted and the underlying image. When using this technique to align two images, it is usually easier if one of the images is first converted to binary using the Make Binary, Trace Edges, or Dither commands. Macros are available in the file “More Macros” for rapidly switching among the different transfer modes.

The foreground color is initially set to black and the background color to white whenever *And*, *Or*, or *Replace* are selected, but you are can vary the foreground and background

colors during the paste operation by clicking (or Option-clicking) in the LUT window. This will produce some interesting, and possibly useful, effects. *Or* mode can be used to color objects in binary images created by *Image* or programs such as by SuperPaint and MacDraw. Simply select the object you want to color, Copy, switch to *Or* mode, then select a color by clicking in the LUT window.

Replace mode replaces the destination pixel with the source pixel if the source pixel isn't equal to white. *Replace* mode is useful for overlaying colored objects with white backgrounds (e.g. text or plots) onto another image.

In *Blend* mode, destination pixels are replaced with the arithmetic average of source and destination pixels. It is similar to an *Add* operation with *Scale Math* checked. *Blend* mode, however, works with true color images, and does not terminate the paste operation. Color images to be blended must have the same color palette.

Clicking on *Add*, *Subtract*, *Multiply* or *Divide* causes the specified image arithmetic operation to be performed and terminates the paste operation. For example, clicking *Subtract* subtracts the selection being pasted from the current window. If *Scale Math* is checked, arithmetic operations are done in two passes. In the first pass, *Image* determines the minimum and maximum gray levels that would result from performing the operation. In the second pass, the image arithmetic is actually performed and the resulting pixel values scaled to the range of 0 to 255. Results are clipped to 0 and 255 if *Scale Math* is not checked. Arithmetic operations are always done on raw pixel values, ignoring any density calibration that may be in effect.

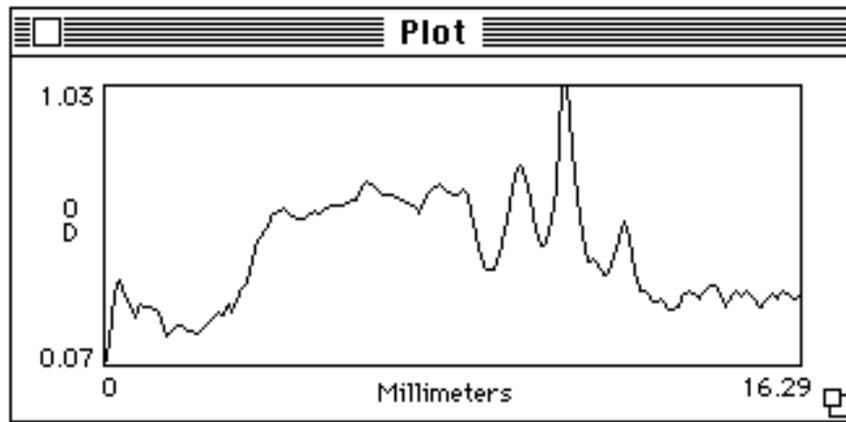
Subtraction is probably the most useful arithmetic operation. It

can be used to subtract the background (the image with features of interest removed from view) from an image. It can also be used to detect differences between two images or for motion analysis.

Selecting *Live Paste* causes the currently pasted selection to use “live” TV camera input. The selection must have been copied from the Camera window and pasted into some other window.

The arrow keys can be used to “nudge” the selection currently being pasted in any of four direction by a single pixel. You can get interesting effects, including an embossed look similar to a bas-relief, by using the arrow keys to offset an image by one pixel, and then subtracting it from itself. To see how this works, try Select All (Command-A), Copy (Command-C), Paste (Command-V), Down Arrow, Right Arrow, and *Subtract*.

Plot



The Plot window is created, or updated, by the density profile tool, the Plot Profile command, or the Calibrate command. The plot can be made larger (or smaller) by resizing the Plot window using the Grow Box in the lower right corner. The Plot window must be the currently active window in order to Print or Copy the current plot. To activate the Plot window, click on it or select Plot from the Windows menu. When active, the Plot window's title bar will be highlighted (as show above), and Plot will be checked in the Windows menu.

The current plot can be copied to the Clipboard using the Copy command. Once on the Clipboard, the plot can be pasted into an image window, or into another application. The plot is copied to the Clipboard in both graphic and text formats. The Graphic form will be used if you paste into a program that deals primarily with graphics, such as MacDraw. The text form (i.e., the pixel values) will be used if you paste into a program that is text oriented, such as Excel.

Whenever the cursor is over the Plot window, X (the pixel number) and Y (the pixel value) coordinate values are continuously displayed in the Values window. In the case of calibration plots, X is the uncalibrated pixel value (in the range

0-255) and Y is the calibrated value. For straight line selections, holding down the mouse button in the plot window causes a cross hair cursor to appear in the corresponding part of the image.

Several aspects of profile plots, such as y-axis scaling and plot size, can be changed using the Profile Plot Options command.

Values

Results	
X:	5.97cm (406)
Y:	7.35cm (500)
Value:	-0.27 (0)
Count:	17
Pixels:	4362
Area:	0.94 square cm
Mean:	0.30 OD (57)
Std Dev:	0.09
Min:	0.07
Max:	0.48
X,Y:	5.48, 1.76
Mode:	0.36
Perimeter:	0.08

The values displayed at top of the Values window are dynamically updated variables that have different meanings depending on which window the cursor is in.

Image Window - *X* and *Y* are the current cursor coordinates, where the origin is at the lower left-hand corner and positive *X* is to the right and positive *Y* is up. (Note, you can change the origin to the upper left using the Preferences command.) *Value* is the gray value of the pixel at the current *X-Y* coordinates. Gray values range from 0 (white) to 255 (black). For density calibrated images, *Value* is the calibrated pixel value and the gray value is shown in parenthesis. In the case of color images, *Value* is the index used by the color look-up table.

LUT Window - *Index* is the look-up table index at the cursor location. *RGB* are the associated red, green, and blue brightness values in the look-up table. You can use this information to help you set the foreground or background grayscale, or color, to a specific grayscale value or index. When using the LUT tool, *Lower* and *Upper* are the lower and upper LUT indexes of the current grayscale or color

palette.

Map Window - When manipulating the Map, *Lower* and *Upper* are the lower and upper LUT indexes of the current grayscale or color palette.

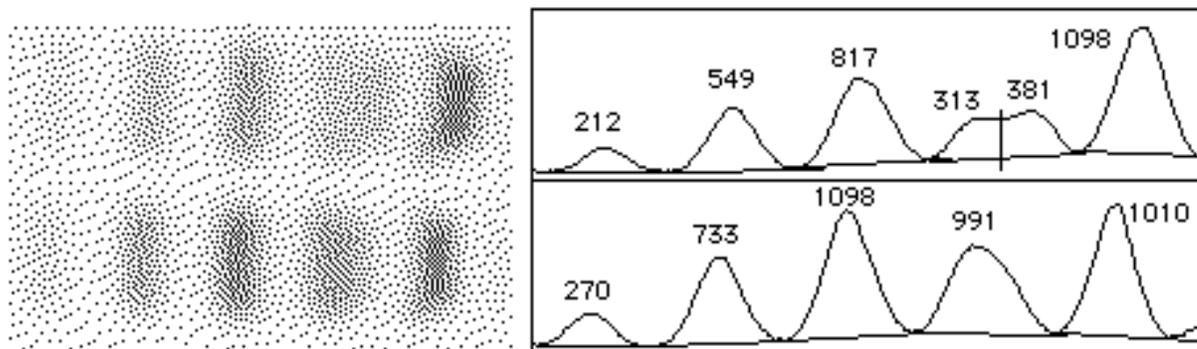
Histogram Window - *X* is the current x-axis (grayscale) value and *Y* is the number of pixels in the selection which have that value.

Plot Window - *X* is the cursor x-coordinate and *Y* is the corresponding plot y value. For calibration plots, *X* is the uncalibrated pixel value (in the range 0-255) and *Y* is the calibrated value.

TECHNIQUES

Analyzing Electrophoretic Gels

Here is one possible procedure for using *Image* to analyze a one-dimensional electrophoretic gel. This procedure also demonstrates some of the less obvious features in *Image*, and also a few shortcuts. Note that this technique cannot be used to compare bands on different gels unless the gels are calibrated to known standards. Also note that the measured peak areas tend to be too small for small peaks (smaller than about 500 pixels). Any results obtained using this procedure should not be trusted without testing using standards with known concentrations or by comparing with results obtained using a densitometer.



- 1) Use the Calibrate command to calibrate the image to standards included in the gel or to a calibrated optical density step tablet. Failure to do this could result in incorrect and misleading measurements. For calibrated images, results are reported in calibrated units such as integrated OD.
- 2) If the commands *Mark First Lane*, *Mark Next Lane* and *Plot Lanes* are not shown in the Special menu then use *Load Macros* to open the file "Gel Plotting Macros" in the

Macros folder.

3) Use the rectangular selection tool to outline the first lane. This is the left most lane for vertically oriented lanes and the top lane for horizontal lanes.

4) Select *Mark First Lane* in the Special menu. A copy of the image will be displayed with the first lane outlined.

5) Move the rectangular selection (by clicking inside it and dragging) and outline (using *Mark Next Lane*) each of the other lanes in succession.

6) Use *Plot Lanes* to generate the lane profile plots.

7) Use the line drawing tool to draw base lines and drop lines so that each peak defines a closed area as shown above. Note that you can hold the Shift key down to constrain lines to be vertical.

8) Measure the areas of the peaks by clicking inside each one in succession with the wand tool.

9) Option-click with the text tool to automatically label the peaks, in reverse order, with the area measurements. The area measurements are also recorded in tabular form, and can be displayed (Show Results) printed (Print) or exported (Export) to a spreadsheet.

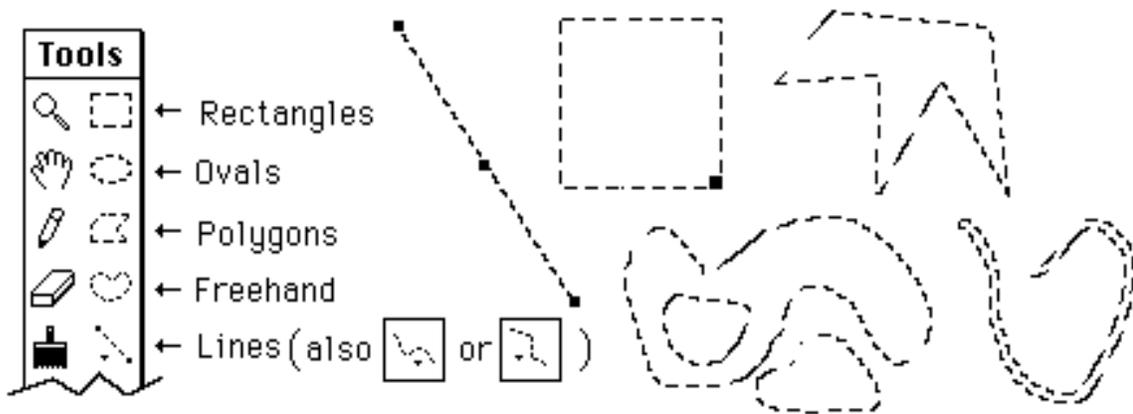
Plot Lanes may fail if it tries to create a plot window that is larger than the Undo buffer. If this happens, you will need to increase *Undo & Clipboard Buffer Size* in the Preferences dialog box, Record Preferences, and restart *Image*.

Note that this macro package changes several of the settings in the Analysis/Options dialog box. It enables *Wand Auto-Measure* so that the area is automatically measured when you click with the wand tool under a peak. It disables *Label Particles* so that peaks are not automatically numbered by the wand tool. It enables *Include Interior Holes*. If this were not done, the wand tool would measure zero area. It enables *Adjust Areas* to compensate for the tendency of the wand tool to underestimate the size of small peaks. The size of small peaks is underestimated because some of the actual peak area is represented on the screen by the pixels which define the boundary, and, on small peaks, the ratio of boundary pixels to interior pixels is higher.

Using Selections

Selections are user defined regions or lines within an image that can be measured, filtered or edited. Region selections are created using the rectangle, oval, polygon or freehand selection tools. Line selections are created using the line selection tool, which has three forms selected from a pop-up menu. Line selections can be straight, freehand or segmented. Selections

are outlined by a moving marquee, sometimes referred to as “marching ants”. Only one selection can be active at a time.



Moving a Selection. Selections can be moved by clicking inside them and dragging. The Values window displays the coordinates of the upper left corner of the selection (or the bounding rectangle for non-rectangular selections) as it is being moved. Notice that the cursor changes to an arrow when it is within the selection. Straight line selections can be moved using the handle (small black box) in the center of the line. If you want to move the *contents* of a selection, rather than the selection itself, do a Copy (Command-C), a Paste (Command-V), then click within the selection and drag. Use the shift key to constrain movement to be horizontal or vertical. The arrow keys can be used to nudge the selection one pixel in any direction.

Stretching a Selection. Rectangular selections can be stretched using the handle (small black box) in the lower right corner. The contents of the selection will also be

stretched if the selection is the result of a paste operation. The width and height are displayed in the Values window as the selection is stretched. Use the arrow keys with the Option key down to stretch a rectangular selection one pixel at a time. Straight line selections can be stretched and repositioned using the handles at the ends of the line.

Adding to a Selection. Hold down the Control key (notice the little plus sign in the cursor) while making a selection and any new selection you create will be added to the current selection. This feature allows you to edit existing selections, or to create discontinuous selections, such as the one above. The Shift key can also be used to extend selections when using either the polygon or freehand tool. Note that it is not possible to measure the perimeter of outlines that have been edited in this way except by doing a Draw Boundary and using the wand tool to recreate the selection. Also note that line selections cannot be added to or subtracted from existing selections, but freehand and polygon selections can be added to or subtracted from line selections.

Subtracting from a Selection. Hold down the Option key (notice the little minus sign) while making a selection and any new selection you create will be subtracted from the current selection. This feature allows you to edit existing selections, or to create selections with holes in them, such as the one above.

Deleting a Selection. To delete a selection, choose any of the selection tools and click outside the selection. Alternately, choose any tool other than one of the selection tools, the magnifying glass, or the grabber hand. Use Restore Selection to bring the selection back after you have deleted it.

Transferring a Selection. A selection can be transferred from

one image window to another using the Restore Selection command. Simply activate the destination window and use the Restore Selection command. The Next Window command (command-‘`’) can be used to activate a series of windows in sequence.

Saving and Restoring Selections.

Selections can be saved to disk using the Save As command (with the Outline option) and restored using Open. Multiple selections can be saved by transferring them to a blank (white) window, using the Draw Boundary command (make sure the boundary is black) for each selection, and saving the resulting binary image as a PICT file. To restore a selection, open the PICT file and click to the left of one of the drawn outlines with the wand tool.

USING *IMAGE* WITH FLATBED SCANNERS

The Acquire command provides direct support for scanners that have Photoshop plug-ins.

Image supports three scanning modes: 8-bit grayscale, 8-bit indexed color and 24-bit color. The plug-in that comes with the LaCie Silver scanner is one that works well with *Image*.

You also have to be careful not to generate images that are too large for *Image* to handle. *Image* was optimized for the 640 x 480 (300K) images produced by frame grabber cards, whereas an 8 x 10 inch page scanned at 300 DPI is 2400 x 3000 pixels (7.2MB), much larger than *Image* was designed to handle. The following table gives suggested maximum scan areas for different scanning resolutions and monitor sizes. *Image* can handle scans somewhat larger than these, but you will probably run into problems if you greatly exceed these recommended sizes.

Monitor 75 DPI 150 DPI 300 DPI

13" (640x480) 8" x 6" 4" x 3" 2" x
1.5"

16" (832x624) 11" x 8" 5.5" x 4"
3" x 2"

21" (1152x870) 14" x 11" 7" x 5.5"
3.5" x 2.75"

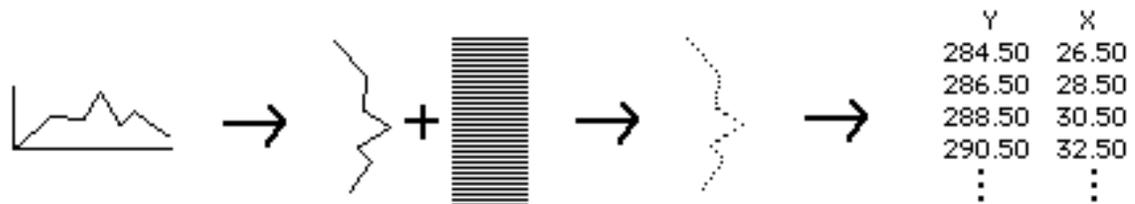
Use the Preferences command to increase the size of the Undo and Clipboard buffers to 600K when working with scans of the size suggested for 16" monitors, and to 1000K for 21" monitors. Note that making the Undo and Clipboard buffers larger than necessary can require a lot of extra memory. For example, increasing the buffer sizes from 1000K to 1500K increases *Image's* memory requirements by 1MB.

You should probably stick to 75 DPI unless scanning small selections. 75 DPI also has the advantage of producing images that are near actual size when displayed or printed, since nominal screen and printer resolution on the

Macintosh is 72 DPI.

RECOVERING DATA FROM LINE PLOTS

Image can be used to recover numeric coordinate data from printed line plots using the following procedure.



- 1) Digitize the plot using a TV camera or flat bed scanner.
- 2) Edit the plot to remove the x-axis, y-axis and labels.
- 3) Rotate the plot 90° clock-wise.
- 4) Create a line mask similar to the one above using the line drawing tool and repeated use of Copy and Paste.
- 5) Convert the line plot to a scatter plot by ANDing the plot with the mask using Paste Control.
- 6) Select *X-Y Center* and deselect *Label Particles* in the Analyze/Options dialog box.
- 7) Deselect *Invert Y-Coordinates* in the Preferences dialog box.

8) Use the Analyze Particles command to record the X-Y coordinates.

Alternately, and much easier, you can use the macros in the file “Line Plots->Data”, which automates most of these steps. Use the wand tool to outline the plot (click to the left of the curve), then use the Clear Outside macro to erase everything except the plot. Next, use Convert Line Plot to Points, which will perform steps 3-8 above. It assumes the active window contains a binary image and you have selected a single isolated line plot drawn on a white background. You can use the Plot Points macro to display the resulting coordinate data.

USING THE OPTION KEY

Holding the Option key down when using many of the commands and tools in *Image* causes alternative functions to be performed.

When using menu commands, you only need to hold the Option key down when you first select the command.

Starting *Image* - Use QuickCapture card instead of Scion card, assuming both are installed

Menu Command Options

Close - Changes to Close All

Save - Changes to Save All

Export (Measurements) - Exports measurement results with column and row headers

Copy (Measurements) - Copy measurement results with column and row headers

Rotate Left, Rotate Right - Erase before rotating

Smooth - More (unweighted) smoothing

Sharpen - Increased sharpening

Trace Edges - Result is not thresholded, allowing you to do it yourself

Analyze Particles - Omit dialog box

Calibrate - Allows you to edit the measured values

Stop Capturing - Omit shading correction

Average Frames - Omit dialog box

Animate - Erase screen to background color before doing animation

Photo Mode - Move window to top of screen before erasing screen

Stack Windows - Move all windows to the “home” position (upper left corner)

Tile Windows - Use “Scale to Fit” mode to draw windows

Tool Options

Magnifying Glass - Zoom out instead of zooming in

Grabber - Scroll all other tiled windows to the same position

Text Tool - Draw results of area or length measurements

Eraser - Pick up background color from image window

LUT Tool - Rotate the LUT

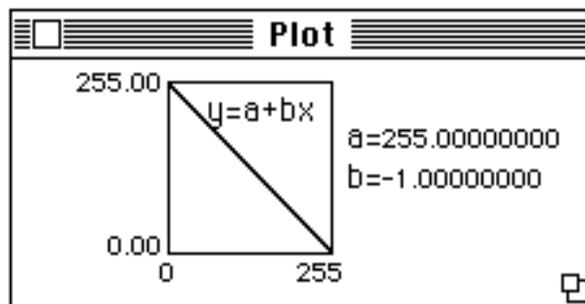
Brush - Pick up foreground color from image window

Eyedropper - Select background color rather than foreground color

QUESTIONS AND ANSWERS

Q. I am used to black having a value of zero, and white a value of 255, but in *Image* black is 255 and white is zero. How can I change this?

A. Check *Invert Displayed Pixel Values* in Preferences, which sets up an inverting density calibration function. This causes pixels values displayed in the Values and Results windows to be inverted.



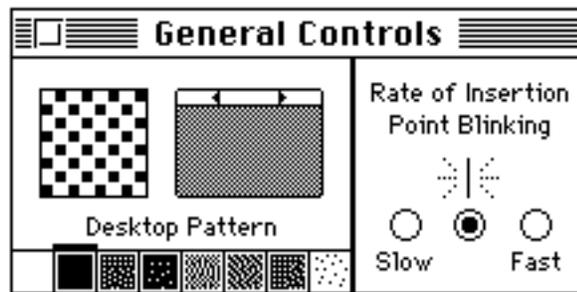
Q. Sometimes, after I have copied an image to the clipboard, the Paste command becomes dim. Why is this?

A. Images copied to the clipboard are stored in *Image's* Clipboard buffer. In some situations, such as

filtering, *Image* has to use the Clipboard buffer for internal operations. When this happens, the Paste command gets dimmed out.

Q. Why do the Finder's icons change color when I run *Image*?

A. *Image* uses all but two of the 256 available screen colors. The two “colors” that *Image* never changes are white (0) and black (255). Objects on the screen that are not black and white are likely to change color when *Image* is being used. To minimize desktop color changes, use the General Controls Control panel to create a gray desktop consisting of a pattern of black and white dots.



Q. Why don't the Halftone and BitMap buttons in the print dialog box do anything?

A. To use the features you must disable *Image's* built-in halftoning by deselecting *Custom Grayscale Halftoning* in the Preferences dialog box.

Q. I want to combine two color images to produce a montage, but the colors are wrong when I Copy from one window and Paste into the other.

A. You can't normally combine images that have different LUTs, but if you check *Keep LUT* when you open the second image (which must be stored as a PICT file)

its pixel values will be remapped to conform to the LUT of the first image. You will now be able to successfully Copy and Paste, since both images have the same LUT.

Q. Is there a version of *Image* that runs on PC compatibles or on UNIX workstations?

A. *Image* has not been ported to the PC or to UNIX and no ports are planned at NIH. However, the complete Pascal source code (~40,000 lines) is available for anyone willing to attempt a port.

Q. Is there some way to more rapidly switch between the 256 color mode required by *Image* and the “millions” of colors mode required by some other programs?

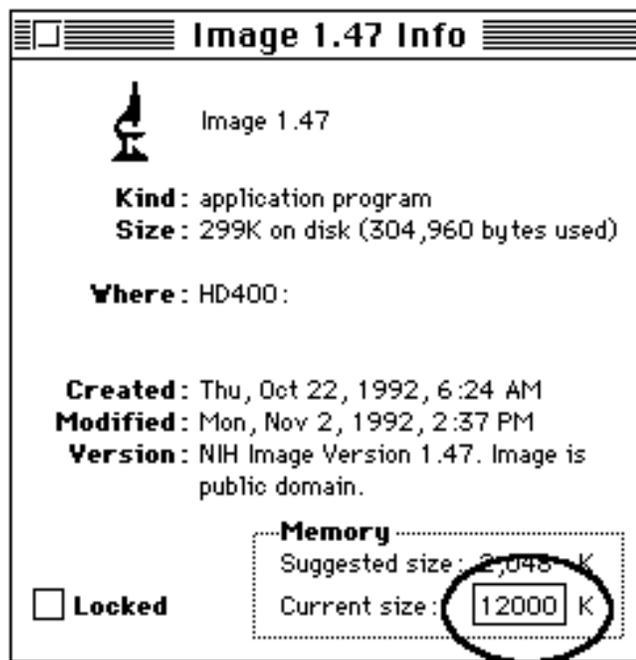
A. There is a free Fkey called Switch-A-Roo that will allow you to rapidly switch between any two monitor depths settings by pressing a few keys. Switch-A-Roo is available by anonymous ftp from [zippy.nimh.nih.gov](ftp://zippy.nimh.nih.gov), in the directory `/pub/image`.

Q. Text looks very ragged when I print an image on my laser printer. Why is that?

A. *Image* treats text as if it were part of the bit mapped image. To create high quality text for laser printer output and slide makers you need to export the image to a multi-layer, object-oriented drawing program, such as Canvas.

Q. I just upgraded my Mac to 20MB, but when I run *Image* I still don't have enough memory. What gives?

A. You need to tell the Finder to give *Image* more memory. Under System 7 or MultiFinder, applications use only as much memory as they are told to. Use the Finder's Get Info command, under the file menu, to increase *Image*'s memory allocation.



A. Macro Programming Language

Image has a built-in macro programming language that can be used for automating complex or repetitive tasks. Macros are similar to Pascal procedures, except the *procedure* keyword is

replaced by *macro* and the procedure heading is a text string that becomes a command in the Special menu when the macro is loaded using the Load Macros command. Macros are stored in text files that may also contain Pascal-like procedures. Macros files are created and edited using Image's built-in text editor. The best way to learn how to write your own macros is by studying and customizing the example macros distributed with *Image* in the Macros folder.

The documentation provided here assumes the reader has some Pascal programming experience. If this is not the case, you will probably need to read an introductory Pascal text book such as "Programming in Pascal" by Peter Grogono, or "Oh! Pascal" by Doug Cooper and Michael Clancy.

```
{Example macro file. Comments such as  
this one go between curly braces.}
```

```
Var  
  x,y,z:real; {Global variables}
```

```
Procedure add(a,b:integer);  
Begin  
  result:=a+b;  
End;
```

```
Macro 'Test [T]';  
Var  
  i,j,result:integer;  
Begin  
  add(2,2);  
  MoveTo(100,100);  
  DrawNumber(result);  
End;
```

```
Macro 'Another Macro [F5]';  
begin  
  beep;  
End;
```

Global variables (optional) are defined at the beginning of the macro file before any procedures or macros. Text within curly braces ({ }) is treated as a comment. The text in quotes following the keyword Macro is passed unchanged to the Menu Manager, becoming a new command at the bottom of the Special menu. Macros may be assigned to keys by enclosing the key character in brackets. Macros may also be assigned to function keys as shown in the example above. A few characters ('; '^; '!'; '<'; '/'; '(') have special meaning to the Menu Manager, and should normally be avoided. You can use / to assign a command key equivalent to a macro, e.g., 'Test

Macro/6'. Use '-' as the macro name to create a dividing line in the Special menu.

Procedures may not be nested inside other procedures, or inside macros. However, unlike Pascal, variables declared in a calling procedure or macro are made available to a called procedure. This feature can be used to get around the lack of VAR procedure

parameters, as shown in the example above. Procedure names are required to be unique in the first twelve characters.

Key Words

MACRO PROCEDURE BEGIN END VAR FOR TO DO
IF THEN ELSE WHILE REPEAT UNTIL

Operators

+ - * / DIV MOD :=
= < > <> <= >= AND OR NOT

Types

INTEGER REAL BOOLEAN STRING

Both integer and real variables are stored internally in extended precision real format, which has a range of 1.9×10^{-495} to 1.1×10^{4932} and 19-20 digits precision. Real numbers are automatically converted (by rounding) to integer without warning as needed. Strings have a maximum length of 255 characters and string comparisons are case insensitive. Variable names must be unique within the first twelve characters.

Built-in Arrays

Although user defined arrays are not supported, most measurement results can be accessed using predefined one-dimensional arrays. These arrays are named *rArea*, *rMean*, *rStdDev*, *rX*, *rY*, *rMin*, *rMax*, *rLength*, *rMajor*, *rMinor*, and *rAngle*. These arrays use indexes ranging from 1 to *Max Measurements*, where the value of *Max Measurements* can be changed in the Options dialog box. Use the *rCount* function to get the value of the current measurement counter and *SetCounter(n)* to change it.

Two predefined arrays (*rUser1* and *rUser2*) can be used to record and display derived results. Unlike the other results arrays, *rUser1* and *rUser2* are reserved for use by macros, and are never written to by any of the commands in *Image*. The column headings used for User1 and User2 can be set from within macros using the routines *SetUser1Label('Label')* and *SetUser2Label('Label')*. After computing a derived result, use *UpdateResults* to redisplay the last line in the results table or use *ShowResults* to redisplay the entire table. Use *SetCounter* to control the number of lines displayed by *ShowResults*. Several example macros distributed with *Image* (in “Measurement Macros”) use these arrays to display derived results.

Histogram values are available using the read-only array *Histogram*, which

accepts indexes in the range 0 to 255. For example, after using Measure, histogram[0] returns the number of white pixels.

Three built-in read/write arrays (*RedLUT*, *GreenLUT*, and *BlueLut*) provide access to the video lookup table (LUT) associated with each open image. These arrays use indexes in the range 0-255 and return intensity values in the range 0-255. Several macros (in “LUT Macros”) that use these arrays are distributed with *Image*, including a macro to export the current LUT as a text file, macros to load various functions into the LUT, a macro to plot the current LUT, and a macro to load a grayscale step function (“Posterize”) into the LUT.

The built-in array *LineBuffer* provides access to the internal line buffer used by GetRow, PutRow, GetColumn and PutColumn. *LineBuffer* uses indexes in the range of 0-4095

and returns pixel values in the range 0-255. Using GetRow, LineBuffer[x] and PutRow to do pixel-by-pixel processing is up to twice as fast as using GetPixel and PutPixel, but is still at least 100 time slower than using compiled code.

The X-Y coordinates of the current selection are available from within macros using the built-in arrays xCoordinates[n] and yCoordinates[n]. The number of coordinates can be obtained using the macro function nCoordinates. The coordinates are relative to the upper left corner of the selection's bounding rectangle. For an example, look at the macro "Plot X-Y Coordinates" in "Measurement Macros".

A four element built-in array (Scion) allows access to the Scion LG-3's I/O registers. The four elements of the array are defined as follows:

Scion[1]	8-bit DAC(A)	read/write
Scion[2]	8-bit DAC(B)	read/write
Scion[3]	8-bit Control Reg 1	read only
Scion[4]	4 digital out bits	read/write

Example macros for setting and reading the LG-3 I/O registers are available in the file "Video".

The data values generated by the PlotProfile and GetPlotData macro commands are stored in a built-in real array named PlotData, which uses indexes in the range 0-4095. The macro "Plot Profile" in "Plotting Macros" illustrates how to use GetPlotData and PlotData.

Built-in Procedures and Functions

(Note that ROI means Region of Interest.)

File Menu

MakeNewWindow('Name')	Use SetNewSize to specify the size of the new window
NewTextWindow('Name',w,h)	Creates a new text window with the title 'Name'. <i>W</i> and <i>h</i>
	(optional) specify the width and height of the new window.
Open('File Name')	
SetImport('string')	Where <i>string</i> contains some combination of: 'TIFF',
'MCID',	'Palette', 'Text', 'Custom', '8-bits', '16-bits Unsigned',
	'16-bits Signed', 'Swap Bytes', 'Auto-Scale', Fixed Scale',
	'Calibrate' and 'Open All'
SetCustom(width,height,offset,slices)	Specifies the <i>width</i> , <i>height</i> , <i>offset</i> , and number of
	of

slices for imported files. The *slices* argument is optional.

SetImportMinMax(min,max)	Disables auto-scaling and fixes the range of Imported files
Import('File Name')	
Acquire('Plug-in Name')	Runs a Photoshop compatible acquisition plug-in. The
plug-in	is assumed to be in the same folder as <i>Image</i> , or use a full path name such as 'HD400:Plug-ins:LaCie Silver Scanner'.
Close	Closes the active window
Dispose	Similar to Close, but user is never prompted to save
changes	
DisposeAll	
Save	Resaves the contents of the current image or text window
SaveAll	
SaveAs	Saves the current image or text window using the window title as the file name. Use SetPicName to change the title of image windows. When saving images, the dialog box should only be displayed the first time SaveAs is called.

SetExport('mode')	Where <i>mode</i> is one of: 'Raw', 'MCID', 'Text', 'LUT', 'Measurements', 'Plot Values', 'Histogram Values' or 'XY Coordinates'
Export('name')	Use SetExport to specify what to export
RevertToSaved	
Duplicate('Window Title')	
GetInfo	
Acquire('name')	Runs the specified acquisition plug-in
Print	Prints the active image

Edit Menu

Undo	
Copy	Copies contents of current ROI to Clipboard
CopyResults	Copies measurement results to the Clipboard
Paste	Pastes into current ROI if Clipboard object and ROI have the
	same dimensions, otherwise, pastes into center of image.
PasteLive	Pastes "live" from video (frame grabber) source
Clear	Erases current ROI to background color
Fill	Fills current ROI with foreground color
Invert	Linearly inverts image or ROI
DrawBoundary	Outlines current ROI using foreground color. Use SetLineWidth to control width of outline.
DrawScale	
SelectAll	
SetScaling('string')	Where <i>string</i> contains some combination of: 'Nearest', 'Bilinear', 'New Window', 'Same Window' or 'Interactive'

ScaleAndRotate(xscale,yscale,angle) $0.05 \leq xscale, yscale \leq 25.0$ and $-180 \leq angle \leq 180$

RotateLeft(b)	Create new window if <i>b</i> true
RotateRight(b)	Create new window if <i>b</i> true
FlipVertical	
FlipHorizontal	

Options Menu

InvertLUT	Inverts video look-up table
SetPalette(string)	Where <i>string</i> is one of: 'Grayscale', 'PseudoColor', 'System Palette', 'Rainbow' or 'Spectrum'
SetFont('Font name')	Font Name=Geneva, Monaco, Helvetica, Times, etc.
SetFontSize(size)	Set font size in points, where $6 \leq size \leq 720$
SetText(string)	Where <i>string</i> contains any combination of: 'Bold', 'Italic', 'Underline', 'Outline', 'Shadow', 'Left Justified', 'Right Justified', 'Centered', 'No Background', or

	'With Background'
SetNewSize(width,height)	Specifies <i>width</i> and <i>height</i> of new windows
ScaleConvolutions(b)	<i>b</i> =true or false. Sets or resets <i>Scale Convolutions</i> flag.
ScaleMath(b)	<i>b</i> =true or false. Sets or resets <i>Scale Image Arithmetic</i> flag.
InvertY(b)	Invert Y-coordinates if <i>b</i> is true
SetPlotLabels(b)	<i>b</i> =true or false
SetPlotScale(min,max)	Set <i>min</i> and <i>max</i> to zero for auto-scaling
SetPlotSize(width,height)	Set <i>width</i> and <i>height</i> to zero for auto-sizing of plots
SetThreshold(level)	0 <= level <= 255. SetThreshold(-1) disables thresholding
AutoThreshold	Set threshold to automatically determined value
SetDensitySlice(lower,upper)	1 <= <i>lower,upper</i> <= 254. SetDensitySlice(0,0) disables density slicing, SetDensitySlice(255,255) enables it.
GetThresholds(lower,upper)	In density slicing mode, returns the lower and upper thresholds. In thresholding mode, lower is set to the

threshold and upper is set to 255. Otherwise, both are set to zero

PropagateLUT Propagates current LUT to all other open images

PropagateSpatial images Propagates current spatial calibration to all other open images

PropagateDensity images Propagates current density calibration to all other open images

Enhance Menu

Smooth Precede with SetOption for unweighted smoothing

Sharpen Precede with SetOption for greater sharpening

Shadow

TraceEdges Precede with SetOption to prevent auto-thresholding

Dither

ReduceNoise

Convolve('Kernel file name') Note that the name can be a directory path such as 'HD80:Image:Kernels:Smooth'

Filter('name') Runs the specified filter plug-in

MakeBinary

Erode

Dilate

SetBinaryCount(n) $1 \leq n \leq 8$

Outline

Skeletonize

AddConstant(n) $-255 \leq n \leq 255$

MultiplyByConstant(n) $0.0 \leq n \leq 255.0$

ImageMath('op',pic1,pic2,scale,offset,'result') Where 'op' is one of 'add', 'sub', 'mul', 'div', 'and', 'or', 'xor', 'min', 'max' or 'copy'. *Pic1* and *pic2* are pic numbers or pid numbers. For each pixel in the selection, the operation is performed, the result is multiplied by *scale*, *offset* is added and the final result is clipped to 8-bits. A window named 'result' is created to store the resulting image.

SubtractBackground('str',radius) Where 'str' is one of: '1D Horizontal', '1D Vertical', '2D Rolling Ball' or '2D Remove Streaks'. Add 'faster' to 'str'(e.g. '2D Rolling Ball(faster)') for faster operation.

ApplyLUT Transforms the pixel data using the current look-up table

EnhanceContrast

ChangeValues(v1,v2,v3) Changes pixels with a value in the range *v1-v2* to a value of *v3*

Analyze Menu

Measure

GetResults(n,mean,mode,min,max) Use after Measure. Values returned are always uncalibrated. Use cValue function to calibrate them.

AnalyzeParticles Dialog box is not displayed

LabelParticles(b) b =true or false

OutlineParticles(b)

IgnoreParticlesTouchingEdge(b)

IncludeInteriorHoles(b)

SetParticleSize(min,max)

ShowResults

ShowHistogram

RestoreRoi Same as the Restore Selection menu command

MarkSelection Same as the Label Selection menu command

SetOptions('string') Where 'string' contains some combination of 'Area',

'Mean',

'Std. Dev.', 'X-Y Center', 'Mode', 'Perimeter'(or 'Length'), 'Major', 'Minor', 'Angle', 'Int. Den.', 'Min/Max', 'User1', or 'User2'. Any variable not listed is disabled.

Redirect(b)	Enable/disable redirected sampling. <i>b</i> =true or false.
WandAutoMeasure(b)	
AdjustAreas(b)	
SetPrecision(digits[,fwidth])	Where <i>digits</i> is the number of digits to the right of the decimal
SetScale(scale,'unit')	point and <i>fwidth</i> (optional) is the field width <i>Scale</i> is the number of pixels per unit of measurement. Set ' <i>Unit</i> ' to 'nm', 'µm', 'mm', 'cm', 'meter', 'km', 'inch', 'ft', 'mile' or 'pixel' or use an arbitrary unit up to 11 characters in length. Use SetScale(0,'pixel') to disable spatial calibration
PlotProfile	and SetScale(0,") to activate the Set Scale dialog box. Replaces Column Average Plot
GetPlotData(count,ppv,min,max)	Where <i>count</i> is the number of values, <i>ppv</i> is the number of pixels averaged for each value, and <i>min</i> and <i>max</i> are the minimum and maximum values. The plot values are returned in the built-in PlotData array. It is not necessary to call PlotProfile before calling GetPlotData.
SurfacePlot	Creates a surface plot of the current image. Use
SetNewSize	to specify the size of the plot.
ResetCounter	Sets the measurement counter to zero
Special Menu	
StartCapturing	Start live video
StopCapturing	Stop live video
Capture	Captures and displays a single video frame
AverageFrames('str',frames)	'str' is some combination of 'Average', 'Integrate' and 'Video Rate Capture' and <i>frames</i> is the number of frames. Default values are used if the arguments are omitted.
SetVideo('string')	Where 'string' is some combination of 'Invert', 'Highlight', 'Oscillating', 'Trigger', 'Blind' or 'Separate'. Any option not specified is disabled.
SetChannel(channel)	Sets the video input channel, where channel=1, 2, 3, or 4
PhotoMode(b)	Set <i>b</i> true to enable "Photo Mode" and false to disable it
Stacks Menu	
AddSlice	Adds a slice following the current slice
DeleteSlice	Deletes the current slice
AverageSlices	Averages all the slices in the current stack
Capture Color	Captures a 24-bit RGB color image
RGBToIndexed('string')	Where <i>string</i> contains some combination of 'System LUT', 'Existing LUT', 'Custom LUT' and 'Dither'. Custom LUT

Project and Dither are the defaults.
Dialog box is only displayed the first time you call Project

Reslice

Windows Menu

NextWindow

TileWindows

ShowPasteControl

Activates the Paste Control window

Miscellaneous

Beep

ChangeValues(v1,v2,v3)
of v3

Changes pixels with a value in the range v1-v2 to a value

ChoosePic(n)
than

Selects Nth image window without activating it. Faster
than SelectPic but changes are not displayed. Also accepts

	PidNumbers(see PidNumber function).
ChooseSlice(n) than	Selects Nth slice in a stack without displaying it. Faster than SelectSlice but changes are not displayed. Use SelectSlice before exiting the macro to make sure the stack is correctly displayed.
DrawNumber(n)	Displays <i>n</i> at the current location(set with MoveTo)
DrawText('text')	Displays text at the current location
Exit	Terminate execution of the macro
GetColumn(x,y,length)	Copies a column of pixels from active image to the line buffer
GetLine(x1,y1,x2,y2,LineWidth)	Returns coordinates and width of current straight line selection. Sets x1=-1 if there is no line selection.
GetMouse(x,y)	Returns location of cursor in local pixel coordinates
GetPicSize(width,height)	Returns <i>width</i> and <i>height</i> of active image
GetRoi(left,top,width,height)	Returns ROI location and size. Sets <i>width</i> =0 if no ROI.
GetRow(x,y,length)	Copies a row of pixels from the active image to the line buffer
GetTime(year, month,day, hour, minute, second, dayofweek)	
InsetRoi(delta)	Shrinks or expands(if <i>delta</i> <0) ROI by <i>delta</i>
KillRoi	Disables the current “marching ants” selection
LineTo(x,y)	Draws a line from current location to (x,y)
MakeLineRoi(x1,y1,x2,y2)	Origin(0,0) is at upper left. Coordinates can be real numbers.
MakeNewStack('name')	Creates a new 1-slice stack. Use SetNewSize to specify size.
MakeRoi(left,top,width,height)	Origin(0,0) is at upper left
MakeOvalRoi(left,top,width,height)	
MoveRoi(dx,dy)	Moves ROI right <i>dx</i> pixels and down <i>dy</i> pixels
MoveTo(x,y)	Origin is always at upper left corner
MoveWindow(x,y)	Moves current window to global screen coordinates (x,y)
PlotXYZ	Plots XYZ coordinate data stored in a text file
PutColumn(x,y,length)	Copies <i>length</i> pixels from line buffer to a column in image
PutMessage('message')	Displays 'message' in a dialog box. Accepts multiple arguments like the Write routine.
PutPixel(x,y,value)	Displays <i>value</i> at location (x,y)
PutRow(x,y,length)	Copies <i>length</i> pixels from line buffer to a row in the image
ResetGrayMap	Equivalent to clicking on reset icon in Map window
SaveState	Saves foreground and background color, new window width and height, status of Invert Y flag, and various ScaleAndRotate and SetScaling parameters
RequiresVersion(n)	Aborts macro if <i>Image</i> version number is less than

specified	
RestoreState	Restore settings saved by SaveState
SelectPic(n)	Activates Nth image window. Also accepts
PidNumbers(see	PidNumber function).
SelectSlice(n)	Display Nth slice in a stack
SelectWindow('name')	Activate the window with the title 'name'
SetCounter(n)	Sets the measurement counter to <i>n</i>
SetCursor('str')	Changes cursor shape. Set 'str' to 'watch', 'cross' or 'arrow'.
SetForegroundColor(c)	0 <= c <= 255, where 0=white and 255=black
SetBackgroundColor(c)	0 <= c <= 255
SetLineWidth(width)	
SetUser1Label('Label')	Replaces label used for User 1 column in Results window
SetUser2Label('Label')	Replaces label used for User 2 column in Results window
SetPicName('Name')	Renames the currently active image window
SetOption	Equivalent to holding down Option key
SetSliceSpacing(n)	Set slice spacing(in pixels) for use by Reslice and Project commands
ShowMessage('message')	Displays 'message' in the Values window. Accepts multiple arguments like the Write routine. Use a back-slash('\') to
start	a new line.
SortPalette	Sorts the current LUT by hue

UpdateResults windows	Redisplays last measurement in Values and Results
UserCode(n,p1,p2,p3) parameters	Calls a user written Pascal routine, where <i>n</i> specifies which routine is called and <i>p1</i> , <i>p2</i> and <i>p3</i> are real input parameters
Wait(seconds) WaitForTrigger	Fractions of a second are allowed, e.g., wait(1.5) Waits for external trigger if using QuickCapture or Scion LG-3 frame grabber, otherwise waits for mouse button
Write(e1,e2,...) Like optional write('M=	Draws text, variables, or constants at the current location. Writeln procedure in Pascal, expressions may have field width specifications in the form e:f1:f2(e.g., 'mean:8:3), where f1 is the field width, and f2 specifies the number of digits to the right of the decimal point.
Writeln(e1,e2,...)	Similar to Write, but does the equivalent of a line feed and carriage return after displaying the specified values.

Miscellaneous Functions

AllSameSize	Returns true if all open images have the same dimensions
BitAnd(n1,n2)	Returns n1 AND n2
BitOr(n1,n2)	Returns n1 OR n2
Button	True if mouse button down
Calibrated	True if current image is density calibrated
cValue(PixelValue) values	Converts raw pixel values(0-255) to density calibrated values
GetNumber('Prompt',default)	Displays a dialog box and returns with number entered
GetPixel(x,y)	Returns the pixel value at (x,y)
GetSliceSpacing	Returns slice spacing(in pixels) of current stack
nCoordinates	Returns the number of coordinates for the current selection
nPics	Returns number of image windows
nSlices	Returns number of slices in current stack
PicNumber	Returns number(used by SelectPic) of active image
PidNumber image	Returns a negative permanent ID number for the current image
PidExits(pid)	Returns true if image with this PidNumber is still open
rCount	Returns current measurement counter value
Round(n)	Converts a real value to integer with rounding
SliceNumber	Returns number of current slice in a stack
TickCount	Returns the number of ticks(sixtieths of a second) since system last started
Trunc(n)	Converts a real value to integer with truncation
UndoBufferSize	Returns the current size of the Undo and Clipboard buffers

WindowTitle Returns a string containing the title of the active window

Math Functions

abs(n)	Returns absolute value of n
arctan(n)	Returns arctangent of n
cos(n)	Returns cosine of n (radians)
exp(n)	Returns exponential of n
ln(n)	Returns natural logarithm of n
odd(n)	True if integer n odd
random	Generates a random number between 0 and 1
sin(n)	Returns sine of n (radians)
sqr(n)	Returns square of n
sqrt(n)	Returns sqrt of n

Paste Control Options (Use immediately after a paste command)

DoCopy	Precede DoCopy, DoAnd, etc. with SetOption to switch paste transfer modes, otherwise the operation is performed
DoAnd	

DoOr and the paste operation terminated.
 DoXor
 DoReplace
 DoBlend
 Add
 Subtract
 Multiply
 Divide

Serial I/O and Strings

`str:=GetString('Prompt','def.')` Displays a dialog box and returns with the string entered. The first argument is the prompting message and the second argument(optional) is the default input string.

`str:=concat(str1, str2,...)` Concatenates a series of strings

`str:=chr(n)` Converts a positive integer in the range 0..255 to a one character string(e.g. `chr(65) = 'A'`).

`n:=ord(str)` Returns the ordinal number of the first character in a string(e.g. `ord('A')=65`). Returns -1 if the string is empty.

`i:=pos(substr,str)` Searches for *substr* within *str* and returns an integer that is the index of the first character of *substr* within *str*.

Returns zero if *substr* is not found.

`n:=StringToNum(str)` Converts a string to a real number. Returns zero if the string contains no digits.

`str:=WindowTitle` Returns the title of the currently active window

`OpenSerial('Options')` Sets up the modem port for serial I/O. 'Options' contains '300 baud', '1200 baud', '2400 baud', '9600 baud' or '19200 baud'; 'no parity', 'even parity' or 'odd parity'; 'seven data' or 'eight data'; 'One stop' or 'two stop'. The default is 9600 baud, no parity, eight data, one stop'.

`str:=GetSerial` Returns the next available character in the serial(modem) input buffer as a one character string or returns an empty string if the buffer is empty.

`PutSerial(str)` Writes 'str' to the modem port. Like the Write routine, it accepts multiple arguments(e.g. `PutSerial('v=',v:1:2)`).

Note that routines that require a file name or window title (MakeNewWindow, MakeNewStack, Open, SaveAs, Import, Export, Duplicate and SetPicName) accept multiple arguments similar to the Write routine, except that numeric fields are left filled with zeros rather than spaces. As an example, `SetPicName('PIC',n:2)` result in window titles in the form 'PIC01', 'PIC02',

'PIC03', etc. Several other routines (PutMessage, ShowMessage, PutSerial) also accept multiple arguments.

B. Frame Grabber Cards

Image directly supports two frame grabber cards for acquiring images from video sources, such as TV cameras and VCR's: the Data Translation QuickCapture and the Scion LG-3. Both cards allow brightness, contrast and pseudocolor to be adjusted during "live" capture. Both allow continuous histogram display and "live" paste, which can be useful for image alignment. For both cards, the fastest screen refresh rate (about eight frames per second) is achieved on 68040 Macs using the built-in video. A 16 inch, or larger, monitor is required to see the entire 640x480 frame without panning.

Image supports the 768 x 512 resolution available with 50Hz (PAL/CCIR) versions of both frame grabbers. It also supports external triggering with both cards. With the LG-3, analog brightness and contrast can be adjusted using the Video Control dialog box. The LG-3 also features a frame buffer that can be expanded to 64MB using standard Mac SIMMS.

1) Data Translation QuickCapture

Part Number: DT2255

Price: \$1295

Requires EP205 Cable Assembly: \$125

Data Translation, Inc.

100 Locke Drive

Marlboro, MA 01752

Phone: 508-481-3700

Fax: 508-481-8620

2) Scion LG-3

Price: \$895

Requires CRGB-LG3 cable for color capture

Scion Corporation

152 West Patrick Street
Frederick, Maryland 21701
Phone: 301-695-7870
Fax: 301-695-0035
D1887@applelink.apple.com

C. Cameras and Light Boxes

Quantitative image analysis using *Image* requires the use of a high quality TV camera and light source. You should select a high resolution solid-state (CCD) monochrome camera designed for imaging applications. There should be a way to disable any automatic gain control (AGC) or automatic black level features. The light source should provide uniform illumination, as well as stable output with normal line voltage variation.

One CCD camera that is well suited for quantitative densitometry is the Sony XC-77. Other CCD cameras to consider include the Sierra Scientific MS-4030, the COHU Model 4815-5000, and the Dage CCD-72. Sierra Scientific, COHU and Dage also sell lenses and filters. When ordering a camera, particularly the Sony XC-77, make sure it comes with all necessary components, such as power supply, tripod attachment (if needed), and documentation.

Imaging Research, creator of the highly regarded MCID biomedical image analysis system for the IBM-PC, makes a stabilized fluorescent light box that provides the uniform illumination needed for autoradiographic densitometry. They also sell several needed accessories, including the Nikon Micro-Nikkor f2.8/55 mm lens, the F-C adapter needed to connect the lens to a TV camera, and the Kaiser RS-1 copy stand. In addition, they sell Sony and Dage cameras.

For digitizing gels, Fotodyne has an unstabilized light box called the VariQuest 100 that is considerable less expensive than the one from Imaging Research. Fotodyne also distributes a program called "Collage" for imaging of electrophoresis gels, blots and autoradiograms.

For specialized applications, Perceptics has a NuBus frame grabber card that supports the 1340X1037 resolution Videk MegaPlus camera, and can supply a version of *Image* that supports the MegaPlus. Photometrics has a cooled CCD imaging system for the Macintosh that supports CCDs with a resolution of up to 2K X 2K. The Photometrics system, however, is not directly supported by *Image*. Dage-MTI has a real-time video processor (the DSP-200) that does real-time averaging and integration to enhance noisy, low intensity images. They also have an image intensifier for CCD cameras.

COHU Inc.

San Diego, California
619-277-6700

Dage-MTI, Inc.

701 N. Roeske Ave.
Michigan City, Indiana 46360
219-872-5514

Fotodyne Inc.

Hartland, Wisconsin
1-800-362-3642
fax: 414-369-7013

Imaging Research Inc.

Brock University
St. Catharines, Ontario
Canada L2S 3A1
416-688-2040

Perceptics Corp.

Knoxville, TN
615-966-9200
fax: 615-966 9330

Photometrics Ltd.

Tucson, AZ
602-889-9933
fax: 602-573-1944

Sierra Scientific

Sunnyvale, CA
408-773-5600

Sony Corporation of America

Component Products Company
10833 Valley View St.
Cypress, CA 90630
714-229-4197
fax: 714-229-4285

D. Alternative Macintosh Analysis Systems

BRAIN

(2-DG and receptor autoradiography)
Image and Computer Vision Center, Drexel
University
Philadelphia, PA
215-895-1381

BDS Image

(Fluorescence microscopy, calcium imaging)
Biological Detection System, Inc.
Rockville, Maryland
301-990-0100, fax: 301-990-8391
72204.70@compuserve.com

DIP Station

(Medical image analysis, 16-bits, surface
rendering)
Hayden Image Processing Group
Boulder, Colorado (whc@po.cwru.edu)
303-449-3433, fax: 303-449-3772

Enhance, Color-It!

(Image editing, Photoshop plug-ins)
Micro Frontier
Des Moines, Iowa
515-270-8109

Image Analyst

Automatix
Billerica, MA
508-667-7900

IPLab Spectrum

(>8-bits precision, 24-bit color, gel analysis,
microscopy)
Signal Analytics
Vienna, VA
703-281-3277, fax: 703-281-2509
d6196@applelink.apple.com

MedVision

(Medical imaging, multi-modality studies, 16-
bits, extendible, FDA approved)
Evergreen Technologies
Castine, Maine
207-326-8300, fax: 207-326-8333
evergreen@applelink.apple.com

NCSA Image, PalEdit, Layout, and Gel Reader (all public domain)

(Scientific visualization, palette editing, gels)
NCSA, Champaign, IL
217-244-0072
Anonymous ftp: zaphod.ncsa.uiuc.edu

Photoshop

(Color image processing, 24-bit to 8-bit color conversion,
file conversion, plug-in modules)
Adobe Systems
Mountain View, CA
415-961-4400

PixelTools, TCL-Image

(Video rate processing, 1340x1035 frame grabber)
Perceptics Corporation
Knoxville, TN
615-966-9200
fax: 615-966 9330

Transform, View, Format, and Dicer

(Scientific visualization, presentation graphics,
volume visualization)
Spyglass, Inc.
Savoy, IL
217-355-6000

VoxBlast

(Volume rendering, video microscopy)
VayTek, Inc
Fairfield, Iowa
515-472-2227

VoxelView/Mac

(Volume rendering)
Vital Images
Fairfield, Iowa
515-472-7726

Ultimage

GTFS Inc.
Santa Rosa, CA
707-579-1733

E. File Formats

TIFF Files Created by *Image*

Bytes 0-7 contain the TIFF header. Bytes 8-129 contain the TIFF Image File Directory (IFD). Within the IFD, bytes 30-31 contain the image width and bytes 42-43 contain the height. Bytes 130-255 are currently unused and are set to zero. Bytes 256-767 contain a 512 byte header unique to the *Image* program. Image data starts at byte 768, stored in row order, one byte per pixel. In the case of a stack, there are two or more consecutive images starting at byte 768 and bytes 516-517 contain the number of images (slices). The TIFF color table, if any, follows the image data. It consists of 256 16-bit red values, 256 16-bit green values, and 256 16-bit blue values. Any additional TIFF IFDs (only needed for stacks) follow the color table. Note that the 16-bit integers containing the width, height, and number of images have the opposite byte order as IBM PC and VAX systems.

TIFF files created by *image* can be read using the Import command by selecting *Custom, 8-bits*, entering *Width* and *Height*, and setting *Offset* to 768. *Slices* should be set to one for a single image and to the number of slices for a stack.

The information provided here should be adequate for writing a program to read a TIFF file created by *Image*. It is not sufficient for creating TIFF files that *Image*, or any other program, can read. More detailed information on TIFF is available via anonymous FTP from [zippp.nimh.nih.gov](ftp://zippp.nimh.nih.gov), in the directory `/pub/image/documents`.

MCID File Format

The easiest way to create variable sized image files that can be read by *Image* is to duplicate the MCID format supported by the Import command. MCID files contain the line width less one in bytes 0-1, the number of lines less one in bytes 2-3, followed by the 8-bit pixel data in row order. The 2 bytes (one 16-bit word) used to store the width and height are stored in Intel/VAX byte order, where the low order byte is first. The following Pascal program is an example of how to create a file that can be Imported into *Image*.

```
PROGRAM MakeRamp;
{
  This example Pascal program creates an image
  file that can be opened using Image's Import command.
}
VAR
  f:text;
  i,line,pixel,PixelsPerLine,nLines:integer;
BEGIN
  write('Pixels Per Line: '); readln(PixelsPerLine);
  write('Number of Lines: '); readln(nLines);
  writeln('Creating image. This may take a few minutes. ');
  rewrite(f,'Ramp');
  write(f,chr((PixelsPerLine-1) MOD 256));
  write(f,chr((PixelsPerLine-1) DIV 256));
  write(f,chr((nLines-1) MOD 256));
  write(f,chr((nLines-1) DIV 256));
  FOR line:=1 TO nLines DO
    FOR pixel:=0 TO PixelsPerLine-1 DO write(f,chr(pixel));
  close(f);
END.
```

F. Program Limitations

There is no arbitrary limit (other than memory requirements) on the maximum number of lines in an image. *Image* uses two 300K buffers as Undo and Clipboard buffers. Many functions will not work with images larger than these buffers. The size of these buffers can be changed in the Preferences dialog box. You must Save Preferences, Quit, and then restart *Image* before the buffer size change will take effect.

The size of internal line buffers is 4096 bytes. This limits the maximum selection width for many functions in *Image* to 4096 pixels.

The maximum number of characters that can be displayed, printed, or copied to the clipboard is 32,700. There is no limit to the number of measurements that can be exported to a text file.

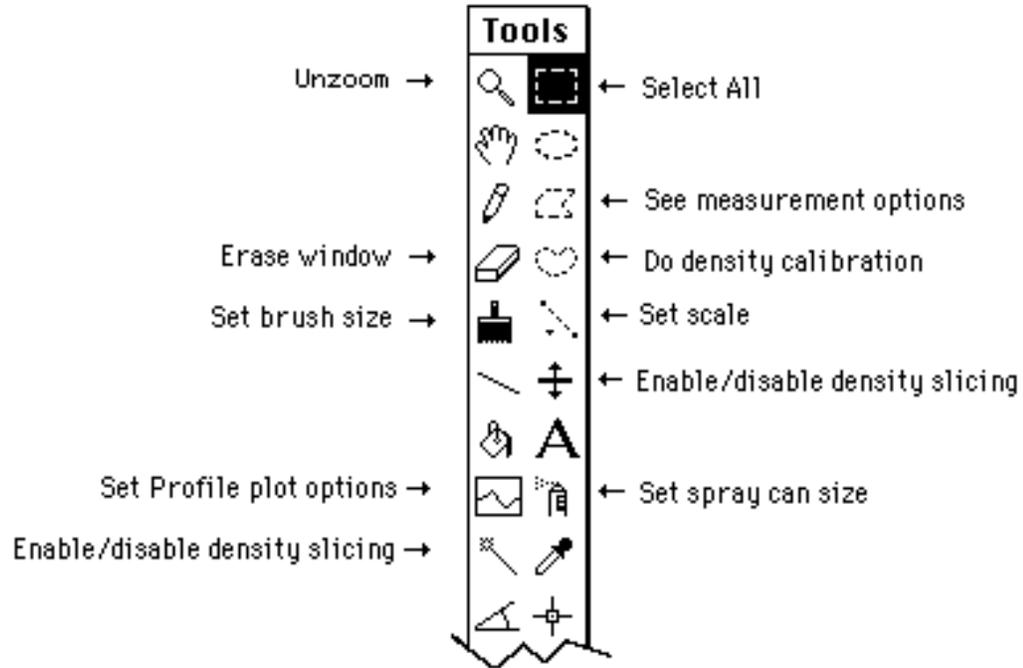
The default maximum number of measurements is 200. This can be changed in the Options dialog box. You must Save Preferences, Quit, and then restart *Image* before the change will take effect.

The maximum size of a macro file is 30,000 bytes. A macro file can contain up to 100 macros. The push-down stack used by the macro language can contain up to 150 variables.

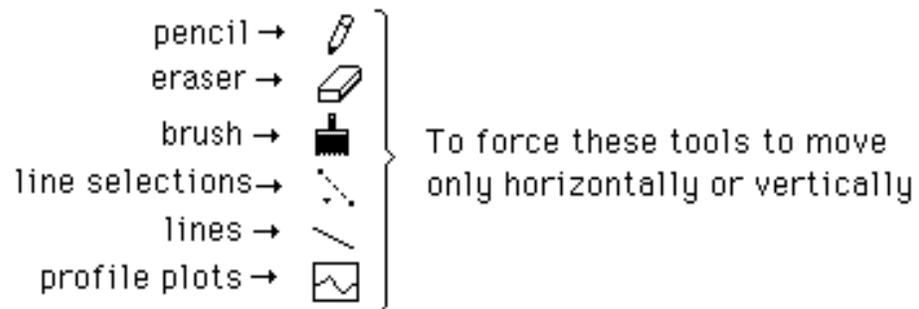
The maximum number of slices in a stack is 256. This can be increased by changing the global constant *MaxSlices* and using Think Pascal to recompile *Image*.

G. Shortcuts

Double-Click on tool to:



To constrain tool functions hold down the shift key:



 To create squares

 To create circles

To move selections precisely horizontally or vertically

H. References

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Digital Image Processing, Kenneth Castleman, Prentice-Hall, 1979.

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I. Updated Versions and Bug Reports

Updates to *Image* are available to Internet users via anonymous ftp from zippy.nimh.nih.gov. Those without Internet access can get updates from many Macintosh bulletin boards and user group libraries. A reasonably current version, including Pascal source code and example images, is available from any of the following sources:

- 1) From a friend. The *Image* program, including source code and documentation, is public domain and may be freely copied, distributed and modified. However, if you modify *Image*, please update the about box before distributing your version of the program.
- 2) Via anonymous FTP from zippy.nimh.nih.gov[128.231.98.32]. Enter “anonymous” as the user name and your e-mail address as the password. The /pub/nih-image directory contains the latest version of *Image* (nih-image154_fpu.hqx or nih-image154_nonfpu.hqx), documentation in Word format (nih-image154_docs.hqx), and complete Think Pascal source code (nih-image154_source.hqx). The directory /pub/image/images contains sample TIFF and PICT images. The directory /pub/image/image_spinoffs contains versions of *Image* extended to do FFTs (ImageFFT), fractal analysis (ImageFractal), and to support quantitative evaluation of cerebral blood flow, glucose metabolism, and protein synthesis (Image/MG). There is a README file (0README.txt) with information on the file formats used.
- 3) Library 9 (Graphics Tools) of the MACAPP forum on CompuServe. Source code is in Library 6 of the MACDEV forum.

- 4) Twilight Clone BBS in Silver Spring, MD. The Clone has 16 lines on sequential rollover, starting with 301-946-8677. To guarantee a V.32 connection, call 946-5034. *Image* is currently available at no charge from the Twilight Clone.
- 5) Subscribe to the NIH *Image* mailing list by sending a message containing the line "subscribe nih-image <your name>" to listserv@soils.umn.edu. Next obtain a list of the available NIH *Image* archive files by sending an "index nih-image" command to listserv@soils.umn.edu. These files can then be retrieved by means of a "get nih-image filename" command. The files are Binhexed and broken into chunks less than 32K in size. The NIH mailing is maintained by the Soil Science Department at the University of Minnesota.
- 6) NTIS (National Technical Information Service), 5285 Port Royal Road, Springfield, VA 22161, phone 703-487-4650, order number PB93-504868 (\$100 check, VISA, or Mastercard). Both the zippy.nimh.nih.gov FTP site and the Twilight Clone BBS are likely to have newer versions of *Image* than NTIS.

Bug reports and suggestions are welcome, as are corrections or additions to this manual. The author (Wayne Rasband) can be reached at the following electronic mail addresses:

Internet: wayne@helix.nih.gov

AppleLink: wayne@helix.nih.gov@internet#

CompuServe: >INTERNET: wayne@helix.nih.gov

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