

tpsDIG2

USER MANUAL

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Getting started

1 Getting started

1.1 Contents

tpsDig version 2

The following Help Topics are available:

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For Help on Help, Press F1

1.2 Introduction

The purpose of this program is to facilitate the statistical analysis of landmark data in morphometrics by making it easier to collect and maintain landmark data from digitized images. Given an initial file specifying the names of the files containing the images of the specimens, the program can be used to mark the locations of the landmarks. It also allows one to capture outlines of structures and linear measurements. The output file is in the [TPS format](#) that can be used as input to other programs in this series (e.g., tpsRelw, tpsSuper, tpsRegr, *etc.*). The output file is a simple ASCII file that can be easily converted into other standard formats (some common operations are provided by the tpsUtil program).

The program can also acquire images directly from a TWAIN compatible camera or scanner or from Microsoft multimedia compatible video files (*.AVI and *.MOV).

Several standard image enhancement operations (such as smoothing, sharpening, and increasing image contrast) can also be applied to make it easier to locate landmarks on the images. These operations are available on the [Image tools window](#).

The program can be used to compute lengths, angles, perimeters, and areas. The profile mode can

be used to compute a horizontal or vertical [brightness profile](#) across an image.



There are now both 32 bit and 64 bit versions of the program. The latter may be useful when processing very large datasets.

1.3 How to use this program

Normally, the **first step** is to prepare an initial TPS file that simply provides a list of the images to be processed (the ID, COMMENT, and VARIABLES fields can also be included if desired). This can be done using a simple ASCII editor such as the Windows notepad program. The easiest way to build this initial file is to use the tpsUtil program, which has an option to automatically build a tps file listing the names of all the image files in a specified directory. If one has just two images the initial file `test.tps` could be prepared as follows:

```
LM=0
IMAGE=canadn0c.tif
LM=0
IMAGE=canadn1c.tif
```




Note: by default only the names of the image files are stored rather than the full file path. Therefore, the image files *must* be stored in the same directory as the TPS file. The “Include image path” menu option will result in the full drive and path being stored in the file. This latter option is useful if, for example, the images are stored on a CD.

The **second step** is to start the tpsDig program and select File|Source|File... menu items and select your TPS file in the Open dialog box. The first image will then be displayed in the main window. If the specimen does not fill the entire image you should consider cropping the image to reduce its size (and hence to speed up its processing). Press  or select Options|Image tools... menu items to display the [image tools window](#). There are Select and IDH_Crop buttons on the Tools page. On the same page are also buttons for flipping the image from left to right and from top to bottom. There are also button for several standard image enhancement operations. It is sometimes helpful to press the drawing pen button, , and make small corrections in the image (especially useful when trying to find outlines automatically). See the Draw page of the [image tools window](#) to change the color and width of the pen. If the original images are BMP files then you should consider converting them to JPG files as they are usually much smaller. This can be done with the tpsDig program by using the “Save image as” item on the File menu.


Alternatively, input can come from a scanner or from an AVI or MOV file. In this mode one acquires images one at a time, digitizes the landmarks, and then saves the new image. The TPS file is then saved at the end of a session. You can combine files from different sessions by using the Append TPS files item from the Files menu. Note: since the TPS files are simple ASCII files you can also combine them using any ASCII editor.

The **third step** is to actually digitize the landmarks, semilandmarks, or the outlines. One can also make various measurements and have them saved to the listing report file or you can add the measurements can be added to the tps file as variables.


You may wish to zoom the image in or out to see more detail or to find your place in a high-resolution image. This can be done most conveniently by enabling the mouse wheel for zooming (see the Options menu). You can also press the + or - zoom buttons on the toolbar to expand or contract the image to a convenient size. In many cases it will be most convenient to click on the “Fit” button (or the

"Fit to window" item in the Options menu) so the image fills the window. Next, select the button for digitizing landmarks () and click on the locations of each landmark. If the image is large you may have to adjust the size of the window or use the scroll bars so that the region of interest is visible (or else zoom it until it fits). If you make a mistake, switch to edit mode () and drag the landmarks to their correct locations. In edit mode you can delete a landmark, curve, or outline by clicking on it with the right mouse button. For low contrast gray images the standard cursor may sometimes be difficult to see. In the Image tools window you can select from among a number of alternative cursors. There is also a draw curves mode (press  or use the Modes menu) that you can use to draw curves to make the digitized data more recognizable (note: these curves are *not* intended for use in computations). Curve points can also be deleted by clicking on them with the right mouse button while in edit mode. When working with large image files you may wish to experiment with the landmark and label size options in the Image Tools window. Labels may not be very visible when the image is zoomed out so you can see the entire image (as when the "Fit" option is selected).

If a structure of known length is visible in the image, one can select the "Set scale" mode and digitize the end points of the structure and enter the known length. The computed scale factor is stored in the tps file using the "SCALE=" keyword. **Note:** the coordinates are always stored in the tps file in pixel units that correspond to the image.



Once the landmarks and curves have been digitized for the current specimen, click on the right arrow button () to move to the image for the next specimen. Alternatively, you can press the right cursor key or press the Alt-N keys. If you made any changes to the image (such as cropping or various enhancements) you will be asked to provide a file name for the changed image. The new file name will be inserted in the TPS file so that the new image will be used in the future.


If template mode (a choice on the Options menu) has been selected then the landmarks from the previous specimen will be copied onto the next image as long as it does not have any landmarks already entered. You can then drag the landmarks to their appropriate locations. Note that the first landmark you move will translate the locations of all the landmarks. Subsequent landmarks can be moved individually. This option was provided to minimize the chance of making the common error of digitizing the landmarks out of order. It is also expected that this mode will speed up the process of digitizing the landmarks (especially when there are many landmarks and variation in shape is small).

Click the  speed button to compute outlines for structures. [Outlines](#) of structures can be obtained automatically if they can be separated from the rest of the image by choosing an appropriate brightness threshold value. The default is a value of 128 (midway between black, 0, and white, 255). You can check this by viewing the thresholded image. Right click on the image to bring up the outline pop-up menu (this view is also available from the Toolbox). The number of black and white pixels is displayed in the status panel along the bottom of the window. If the scale factor has been set then the area is displayed in user units. By default, the program assumes that the structure is light against a dark background but this can be changed from the Toolbox. The area of an enclosed region can also be computed once its outline has been captured by selecting "Enclosed area" from the pop-up menu. Note there is an item on the Options menu to set whether outlines are to be captured in a clockwise or counter clockwise direction.

Click on the ruler speed button to make linear measurements. These will be in pixels unless a scale has been set. A special cursor will be displayed when in measurement mode. Click on an initial point and then the end point of the measurement. The value will be displayed at the bottom of the window. If you then right-click on the image a pop-up menu will allow you to select saving the measurement in the report listing file or else as a value in the variables field. A pop-up window will show a preview of what is to be stored. You can edit this if you wish. The angle measurement speed button allows one to measure angles using three mouse clicks. The first click should be at the end of one ray, the second at the origin, and the third at the end of the second ray. Click on the "Refresh display" item in

the Options menu to erase these measurement objects from the display (you can also right-click on an object and select Delete from the menu).

You may click on the left arrow () and go back and review (and correct in Edit mode, press ) previous specimens. Alternatively, you can press the left cursor key or press the Alt-P keys. Note: in template mode landmarks will *not* be copied onto a new image if any landmarks have already been recorded for that image.

When work for this session has been completed click on the save button to save your work to a TPS file (press ). You can also use the Save data as menu to save the data in the NTS file format. Note that NTS files cannot be read back into the tpsDig program and they also do not support outlines, curves, and comments.

There are additional features that may sometimes be useful. See the [Using the curves tool](#) topic for a convenient way to enter semilandmarks. See Paint mode and [Profile mode](#).

The program can be run from the command line with the file name given as an argument. You can also drop an input file onto the tpsDig form or onto the tps icon from the Windows Explorer but the program cannot be run in a batch mode.

There are now 32 bit and 64 bit versions of this program. The latter may be helpful when working with many high resolution images.

On some computers there may be a problem when the program attempts to save configuration information in an INI file. You can add the -E parameter to the Windows shortcut icon to force the program to save the INI file in the same directory as the program itself. Follow [this link](#) to see how to do it.

1.4 Uninstalling this program

You can use either the uninstall icon for this program or the Windows Add/Remove icon in the Control Panel. Note: if you have used the help file or added additional files to the examples directory then you will get a message saying that all of the files could not be removed. In that case you will need to manually delete the directory into which you installed this program.

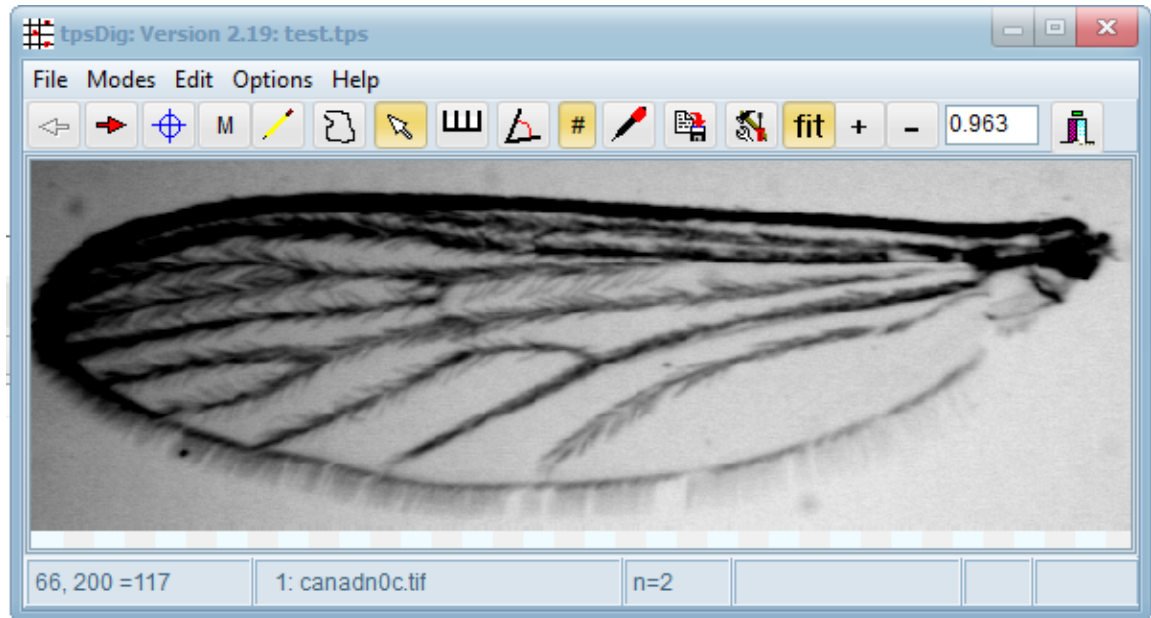
To remove this program manually you need to delete the program and help files located in whatever directory you installed this program.

Using the program

2 Using the program

2.1 Main window

This window displays the current image. In addition, there is a toolbar and a menu.



The body of the window displays the current image (once it has been selected by using the menu). The **status panel** at the bottom of this window shows the following information:

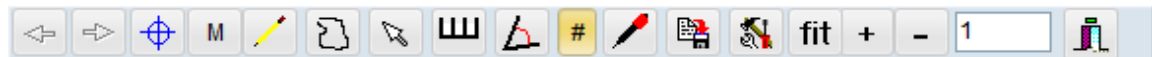
1. The current x,y coordinates and brightness value for the current position of the mouse on the image.
2. The name of the current image file.
3. The total number of specimens in the file.
4. The number of landmarks that have currently been marked. In curve mode (using the pencil tool) the current curve number and point number are displayed. Once one has more than two points recorded for the current curve then the enclosed area will also be displayed here. Click on it to save it to the [listing window](#).
5. In template mode a code is given to indicate whether the first, second, or more landmarks have been edited.
6. The scale factor (if any) for the current specimen.

The **menu** provides the following operations and options:









1. **File** (input source [file or scanner], go directly to a particular specimen in the file, save data [TPS file format], clear data [erase all landmark and curve information], save image, save screen [image plus any landmarks and curves], print image, and print screen [includes any landmarks and curves]). You can also append another TPS file to the end of the current information in memory. Note: files can also be loaded from the command line or by dragging and dropping onto the main window. The "Clear data" item erases all of the data from the current tps file (you may never need use this except option when practicing using the program).
2. **Modes** (digitize landmarks, draw curves, edit mode, [outline mode](#), paint mode, measurement mode, and [profile mode](#)).









3. **Edit** (copy screen including and landmarks, outlines, etc. or just the image to clipboard so you can paste it into another program).
4. **Options** (label landmarks, template mode, specimen information, set scale factor, image tools). The "Query save image?" option will (by default) allow you a chance to save any images that you modify or capture directly from a scanner or a multimedia file. You can also turn this off which might be convenient when working with multimedia files. There is an option (on by default) to allow one to toggle between landmark and edit modes by simply right-clicking on the image in a region where there are no landmarks, curves, or outlines. There is also an option to specify whether outlines are to be captured in a clockwise or counter clockwise direction. Note that setting this option does *not* change how *previously* captured outlines are stored. If the "Beep on landmark added" is checked then the program will beep every time a landmark is added.
The *zoom* options allow one to zoom the image in or out, automatically zoom the image to fit the window, retain the current zoom factor when changing to the next specimen (only works when the automatic zoom is turned off).
5. **Help** (contents, search, about).

The **toolbar** provides convenient buttons for the most common operations.



A description is given below.

1. : previous specimen. Displays the previous image (if there is one).
2. : next specimen. Saves the current landmark information and displays the next image.
Note: if the image input is from a scanner then this will acquire the next image. If input is from an AVI or a MOV file then this will capture the next image from the [Multimedia Input window](#). Alternatively you can position the Multimedia input window manually and then click the right arrow to capture the current frame.
3. : digitize landmarks mode. Displays a cross-hair cursor that records a landmark when the left mouse button is clicked.
4. : insert a missing landmark. The count of landmarks will be increased each time this button is clicked and a point corresponding to the missing landmark will be displayed at the upper left corner. Alternatively, in edit mode one can right-click on a landmark and indicate that it is missing.
5. : draw curves mode. Displays a pencil cursor that you can use to draw a connected line segment each time the left mouse button is clicked. Press the right mouse button or click on the Edit mode button on the toolbar to start a new curve. See the [Using the curves tool](#) topic for more information. The area of the enclosed region is also computed.
6. : edit mode. Displays an arrow cursor that can be used to adjust the positions of the landmark and the curve points. Press the left button and then drag the point to a new location. Right click to display a popup menu of choices.
7. : measure mode. Displays an arrow cursor that can be used to mark the ends of a linear measurement. The value in pixels or user units is displayed at the bottom of the window. Right-click on the image to save the measurement to the report listing file or to save it as a variable.
8. : angle measure mode. Use three mouse clicks to measure an angle in degrees. Right-click on the image to save the measurement to the report listing file or to save it as a variable.
9. #: label landmarks (turns labeling on and off).

10.  Automatically compute and outline around an object at a particular threshold. The enclosed area and perimeter can also be computed.
11. : A save dialog box will be displayed to allow you to save the currently accumulated data.
12. : Show image tools window. It provides many important options such as the color and size of the landmark points and their labels, image enhancement operations, setting a measurement scale, and others.
13.  zoom to fit the image to the current window. This may require one to set larger label sizes unless the sizes are in screen coordinates rather than in image coordinates.
14.  "Paint" directly on image (e.g., to close gaps for the outline procedure). The Undo and Redo items on the Edit menu can be used to erase mistakes.
15. : Zoom in to make image larger by 10% each time. The zoom factor is displayed (and can also be edited directly, click out of the edit box to effect your changes).
16. : Zoom out to make image smaller by 10% each time. The zoom factor is displayed.
17.  This control displays the current zoom factor. One can also enter a value to directly specify an amount of zoom. The fit to window mode should be turned off when you do this.

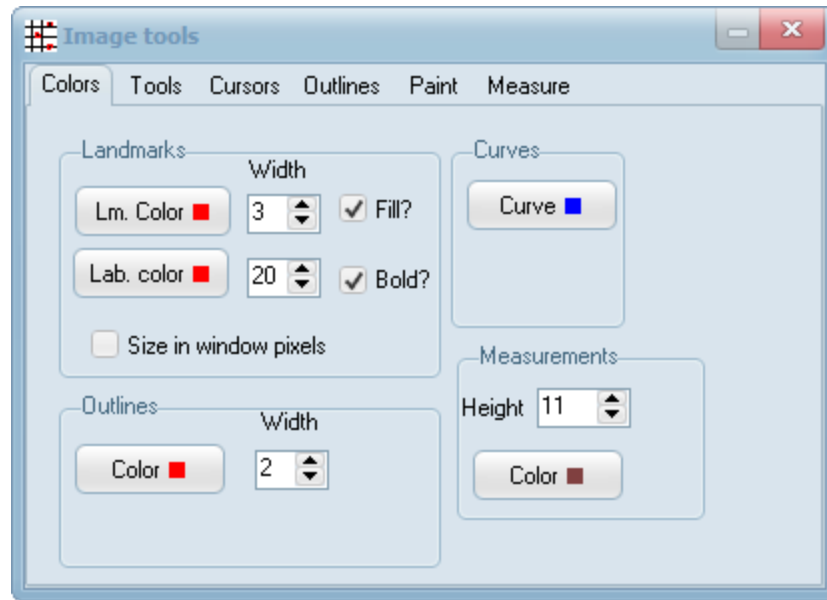
While one usually loads files from the Files|Open menu, you can also drag and drop files from the Windows Explorer anywhere in this main window to load the files. Note that when no specimen has been loaded clicking on most of the buttons will have no effect.

2.2 Image tools window

This window displays a notebook dialog box with tabs corresponding to several pages of options.

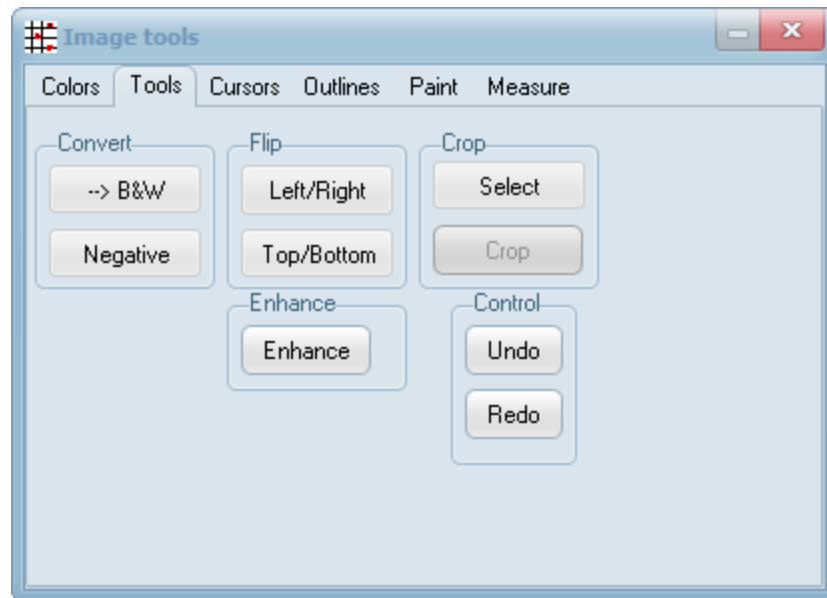
Description of the pages:

Colors tab: you can select the color and size of points used to indicate the landmarks, background curves, and outlines. The "Size in window pixels" check box is to select whether the size units are in pixels of the open window or the pixels of the original image. This should usually be checked when using the zoom option on large images. You can also control the color and size of the labels and the color used for measurements.

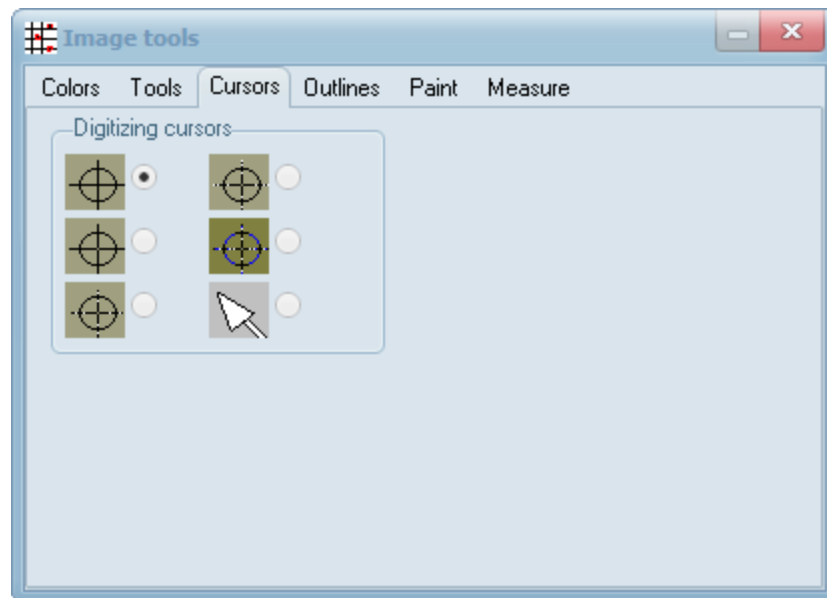


Tools tab: The buttons on the toolbar provide the following operations on the current image (note the Undo & Redo buttons in case the "enhancement" makes the image worse):

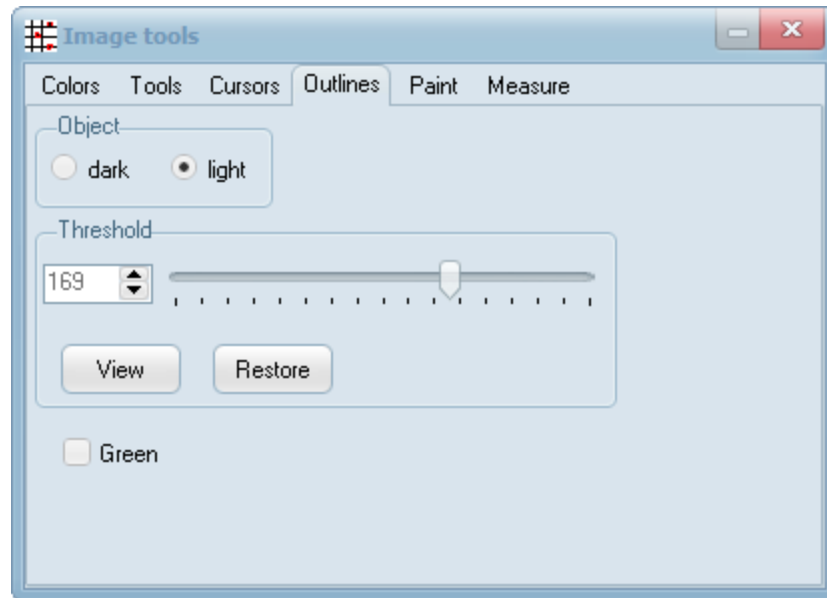
1. Convert color image to black & white (gray-scale). The red, green, and blue brightness values are simply averaged.
2. Perform various image enhancement operation (the ["Enhance" button](#)). Some of the "enhancements" can have rather strange effects. The window just shows a preview. The image is not modified until you click on the "OK" button. Note: if the crop or resize operations are selected from the enhancement window then any existing for that image will not be adjusted to match the new dimensions so they should be used **before** landmarks are recorded for the present specimen.
3. Convert an image to its negative (changes from a positive image to a negative and vice versa).
4. Perform image smoothing to remove any fine-scale noise in the image. A 3x3 grid is used. The image will first be converted to Gray-scale if was not already.
5. It is often useful to crop an image to reduce its size to a selected region. First click on the "Select" button and then use the mouse to drag a rectangle around the desired region on the screen. Then click on the "Crop" button. Only the part of the image *within* the rectangle will be saved if you answer "yes" to the confirming prompt (no changes are made if you click on the "No" button). The positions of any landmarks within the selected region will be adjusted for the current image dimensions.
6. Flip image left to right, i.e., *reflect* the image from left to right. Perform this operation before landmarks or outlines are recorded.
7. Flip top to bottom, i.e., *reflect* the image from top to bottom. Perform this operation before landmarks or outlines are recorded.



Cursors tab: click on a radio button next to the cursor you would like to use to digitize. Low contrast gray images often require darker or lighter cursors.

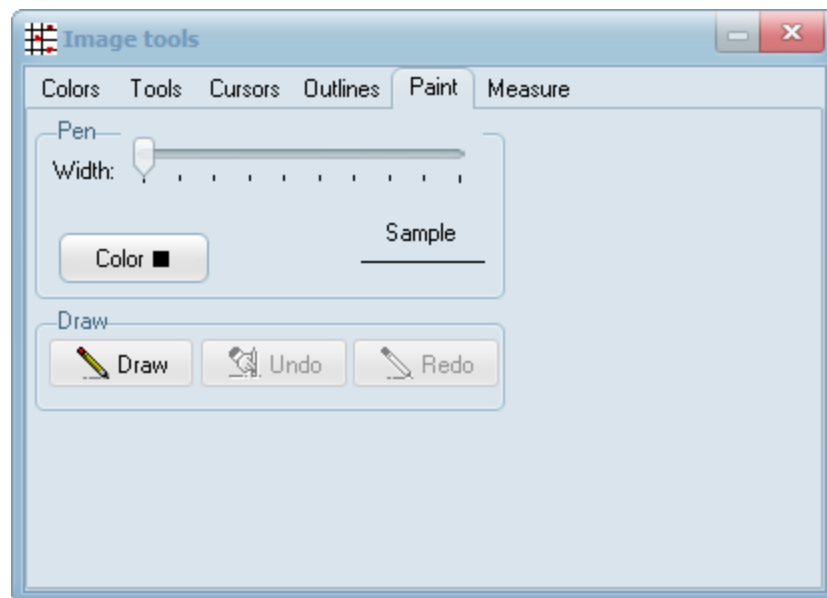


Outlines tab: You can specify the threshold and whether the object is dark against a light background or light against a dark background. There are also buttons to allow you to view a thresholded image and to refresh the display.



Paint tab: This page allows one to change the pen width and color to be used when drawing directly on the image. This can be useful to close small gaps in the image so that outlines can be located automatically. A sample line is shown so that you can judge the appropriate size and color to use.

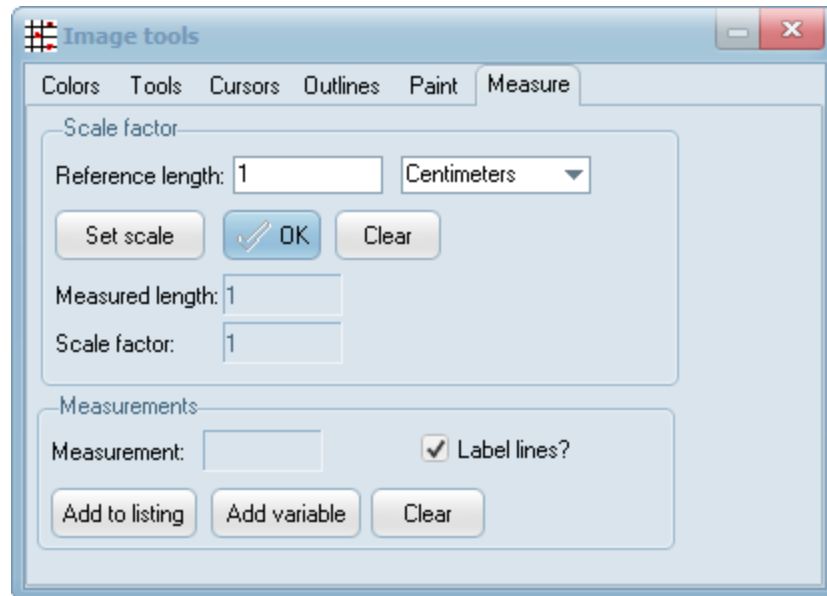
Note: the undo button can be used to correct an error but only the previous 9 changes can be undone.



Measure tab: This page allows one to set a scale and to measure lengths and angles. One can also specify the units (used only for labeling the output). Measurements can be added to the listing file or else added as descriptive variables for each specimen (this information can be put into matrix form using the tpsUtil program). To set a scale factor, enter the known length of a structure in the edit box and then digitize the two endpoints of the structure. Enter just the numerical value, do *not* enter the units. Press the OK button to accept the scale factor or the cancel button to ignore any changes you may have made in the scale factor. Subsequent images you digitize are assumed to have the same scale factor unless you explicitly give them their own scale factors. Using this feature causes the "SCALE=" keyword to be inserted in the output file. The scale factor is the entered length in user

units divided by the measured length in pixels. It also scales the coordinates appropriately (by default the coordinates are in pixel units). The scale factor can also be recorded in the [listing window](#). The scale factor is taken into account in the computation of image areas, perimeters, and linear distance measurements. It has no effect on the landmark coordinates – they remain in pixel units.

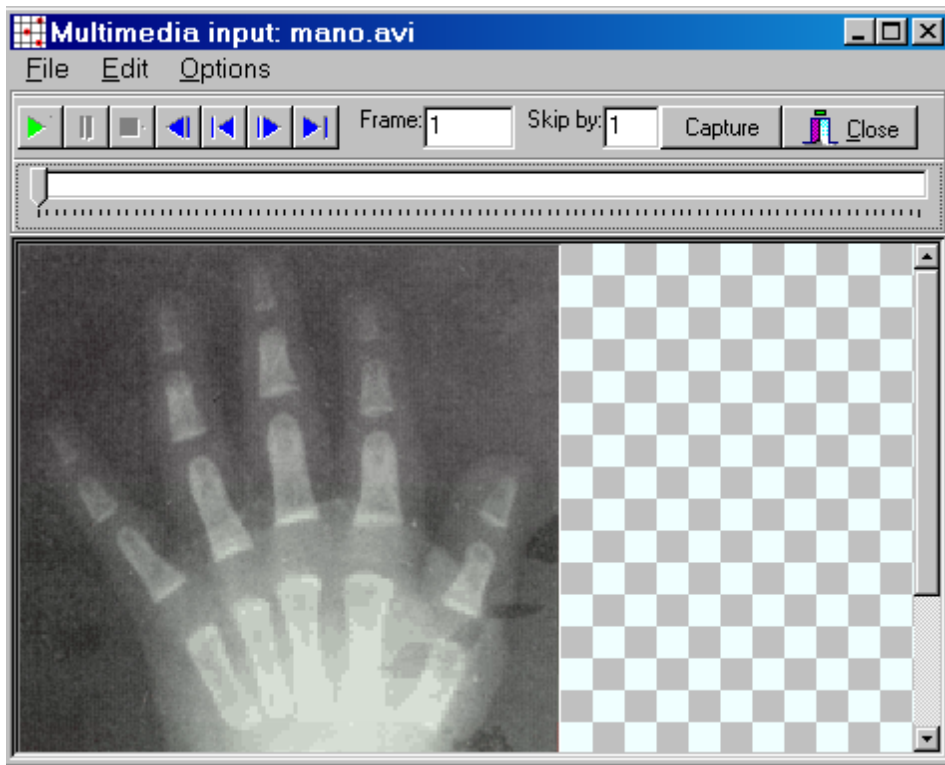
Note: the units are just used for a label – they are **not** taken into account in any computations so the same units should be used for all specimens (i.e., do not say that some are in mm and others in cm). See the "Colors" tab to set the color of the lines used to make measurements. The default is black and that may not be very visible on dark images.



For more information about image enhancement operations see, for example, Rohlf (1990).

2.3 Multimedia input window

This window displays frames from an AVI or MOV file and transfers selected frames to the main tpsDig window.



The VCR type controls enable one to move forward and backward through a file to select the desired frame (the frame number will be displayed). The progress bar shows the current position in the file.



The buttons above correspond to Play, Pause, Stop, rewind to beginning, backup frames (by the step size), advance frame (by the step size), and move to the end of the file. The frame number displays the current frame number. The Skip by window allows one to choose the increment for advancing through the file (may be useful when there are many frames).

Click on the "Capture" button to transfer the current image to the Main window. Equivalently, you can click on the right arrow button in the main window to capture the currently displayed frame. Before the image will be transferred to the Main window you will be prompted for a file name for the image currently displayed in the main window if the "Query save image?" option is checked.

The name of the file and the current frame number will be stored in the [comments field](#) when a frame is captured. This information will be saved with the TPS file.

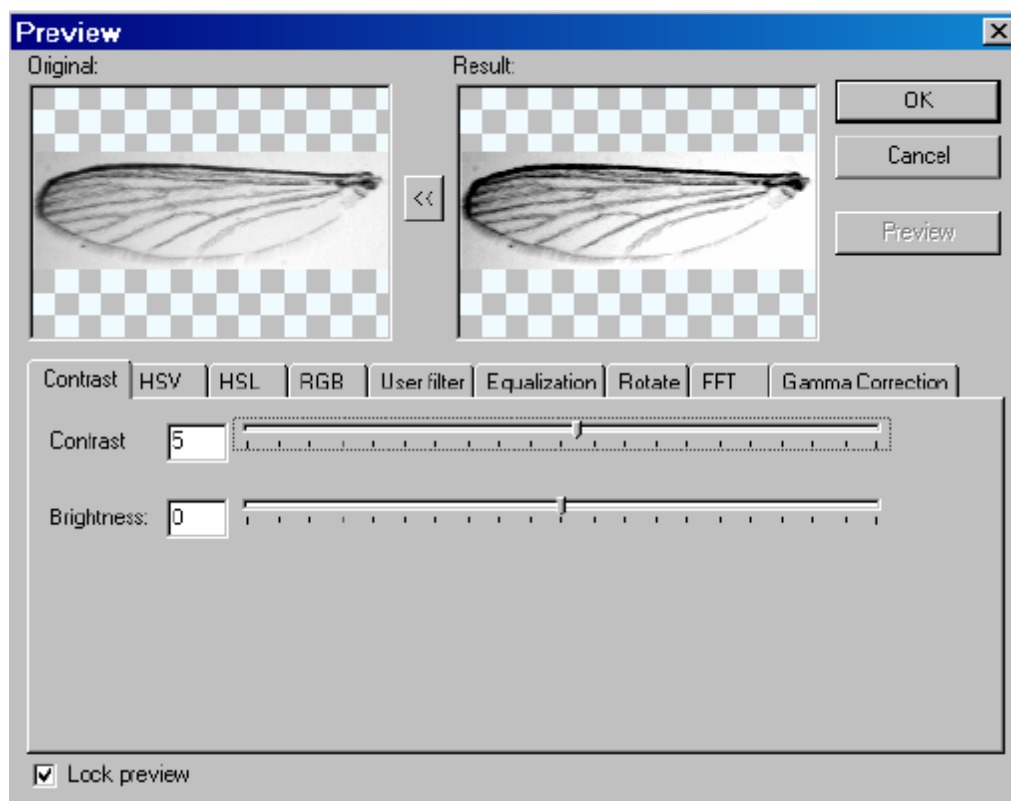


Note: make sure that this window is fully open and clear of any overlapping windows before you click on the Capture button or else parts of these other windows may be included in the image.

2.4 Image enhancements window

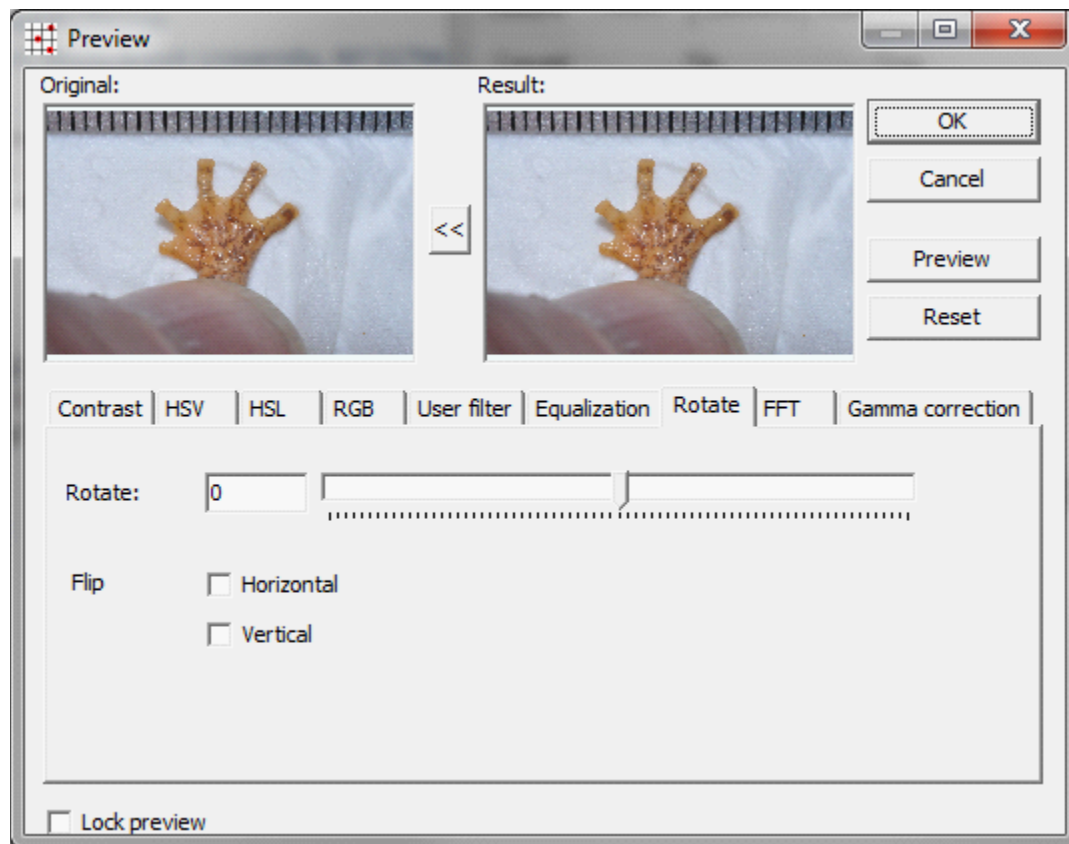
This window provides various standard image enhancement operations. The screenshot below shows the contrast/brightness page. Move the sliders to increase or decrease the effect. Click on the "Lock preview" box to display the changes continuously. Click the "OK" button to accept the change and

close the window. If you would like to accept the change but also try additional operations then click on the button between the Original and Result windows.



The other tabs provide access to other image operations. The “User filter” page has several predefined operations that can be tried. The edges and high pass operations are often useful to bring out detail in an image. A low pass filter smoothes an image and may make the automatic outline detection more reliable. One can also enter values directly for the filter values. These can then be saved to a file and reloaded later.

The following shows an example of the rotate tab.

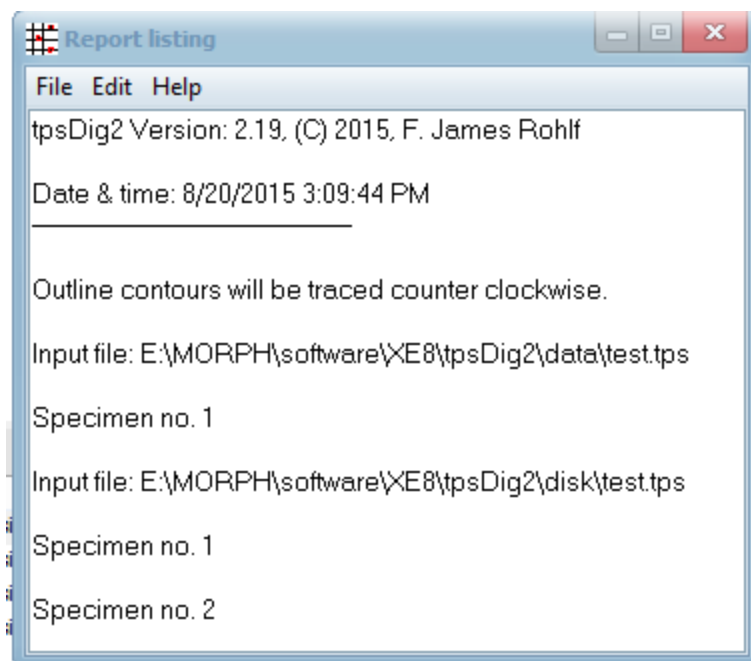


Once you return to the main tpsDig window and try to move to the next specimen you will be asked whether you wish to save the changed image. You may either store it under the same name (which deletes the original file) or else give it a new name.

Some of the enhancements can make unexpected changes to the image. They are not actually applied to the current image until you click on the "OK" button.

2.5 Output listing window

Information about the input file will be automatically written to this window. In addition, you can click on the status panel that shows the enclosed area and that will also be added to this window. If a scale factor is set then that information is also recorded in this window.



The information in this window can be saved to a file, copied and pasted to another program, or printed.

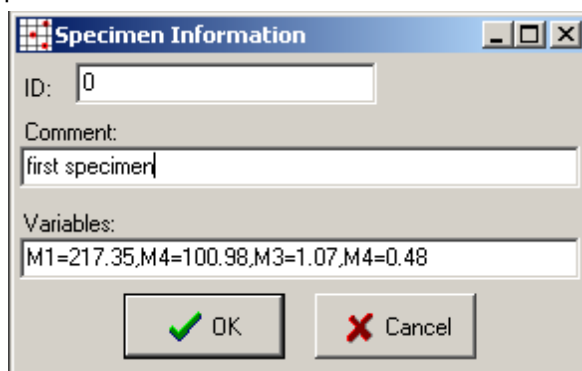
2.6 Profile window

This window displays a brightness profile plot for the currently selected horizontal or vertical line across the image in the main window. Tic marks are displayed horizontally for every 10 pixels along the profile. The brightness values range from 0 (black) at the bottom to the maximum observed in the profile. Tic marks are shown along the vertical axis for every 10 levels of brightness. The Options menu can be used to set the width of the band can be set from 1 to 10 pixels. This operation is performed on the original un-zoomed image.

This plot can be copied to the Windows clipboard as a bitmapped image or saved to disk as a BMP file.

2.7 Specimen information window


This window displays edit controls that allow you to provide the following information for each specimen:




- identification code (e.g., specimen number),
- comment (whatever information you would like to add), and
- variables (a list of numerical codes separated by commas that may be used later by other software to sort the specimens into groups). While no particular format is *enforced*, the intended format is "M1=2.543,A=6,S=0". Linear distance measurements can be automatically added to this window (by selecting "save as variable" from the pop-up menu obtained by right-clicking on the image after a measurement is made).

2.8 Outlines

tpsDig can be used to automatically compute outlines around structures that are either dark against a light background or light against a dark background. There is a spin control in the [Toolbox](#) that allows you to specify the threshold. The default is 128 (where black = 0 and white = 255). The view button displays the image distinguishing pixels that are above and below the threshold (the number of pixels above and below the threshold is also displayed since that is sometimes useful to measure the area of a complex object).

To find an outline, **first** check the Toolbox options (light vs. dark and the threshold) to make sure they are correct. It is also often useful to smooth the image somewhat (unless you are interested in using the outline to compute its fractal dimension). One may also need to make small corrections to the image so that complete outlines can be found automatically. This can be done by clicking on the pen icon, , on the toolbar. You can specify the width and color on the Draw page of the [Toolbox](#). You also have to consider whether to trace the outlines in a clockwise or counter clockwise direction (see the "Clockwise outlines" item in the Options menu). The choice does not usually matter but you must be consistent across all specimens. Note that setting this option only affects how future outlines are captured. It does not change the storage of previously captured outlines.

Second, click on the Outline speed button  on the toolbar. The cursor will change to indicate that the program is now operating in outlining mode. Click with the left mouse button on or slightly to the *right* of the object of interest. The program will then search to the left to find the left side of the object and circle around the object until it finds its starting point. A message will be displayed in the status window indicating either the number of points in the outline or whether the search failed (either no object was found to the left or the outline was too long). By default, the outline will be drawn in yellow.

Third, press the right mouse button to obtain a popup menu that will allow you to accept (i.e., save) the outline in several formats.

X,Y-coordinates: x,y coordinates of points will be stored.

chain code: chain codes for points around outline will be stored. The x,y coordinate of the starting point will also be recorded.

X,Y coordinates of radii: x,y coordinates of the tips of equiangular radii will be stored. The radii are computed from the centroid of the enclosed region.

Radii: lengths of equiangular radii will be stored. Points will be deleted from the outline if necessary in order to make the lengths of the radii unique. The radii are computed from the centroid of the enclosed region.

This pop-up menu also allows the computation of the enclosed area and the perimeter of the outline.

Except for chain codes, you can specify less than the actual number of points so that all outlines will be recorded with the same number of points. On the Options menu one can specify whether the new

number of points are to be selected based just on counting points or by computing the length of the outline. The results are usually similar but selecting based on outline length is probably more desirable. You can also discard the outline, view the thresholded image, refresh the display, or compute the enclosed area. The area of an enclosed region in pixels or user scaled units is displayed in the status bar along the bottom of the window. Once you accept an outline it is redrawn in red (you can change the default outline colors in the toolbox).

You can compute any number of outlines for each image and store them in either format. There will be no warning messages about inconsistencies between images. You must enforce whatever restrictions are required by software that will eventually read the file. The program will warn you if the numbers of landmarks (which can be zero) are not the same for all specimens.


Outlines can be deleted when in Edit mode. Right click the mouse while pointing to an outline to popup a menu that will allow you to delete the outline. A message will be displayed in the status panel indicating which outline will be deleted.

Computing outlines will introduce additional keywords in the output file. In the TPS file the "OUTLINES=" keyword will indicate the number of outlines and "POINTS=" or "CHAIN=" will indicate the number of points in the outline that follows. The chain codes values are preceded by a line giving the starting x and y coordinates for the outline. "RADII" and "RADIIY" codes will be used to indicate outlines stored as equiangular radii.

Note: one can also record the coordinates of points around the outline of some structure by hand using the pencil tool. When using this tool the enclosed area is computed as one goes along. Note there is an option in the Options menu for complete vs. partial outlines.

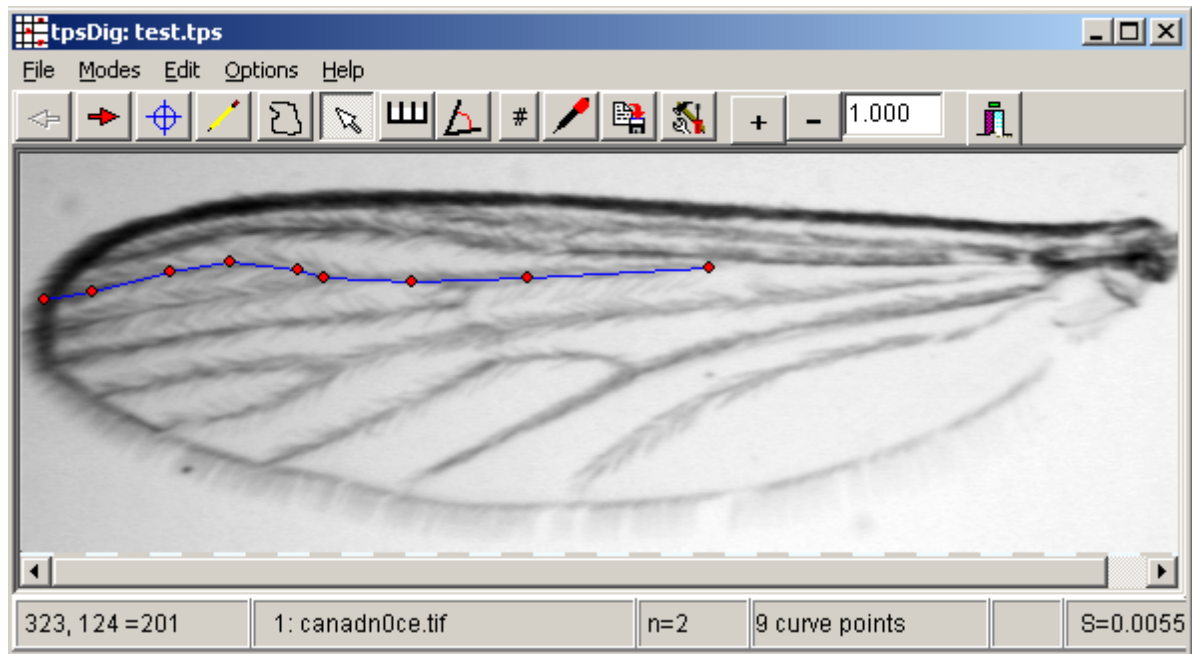
Note: If one intends to use the method of **sliding semilandmarks** for the outline points then one should record the points using the landmark or the [curve drawing tool](#) rather than an automatically captured outline. This is because one usually just needs to have just a few well-spaced points from only parts of an outline and one must start and end with a landmark. One can use the tpsUtil program to convert these curve points to landmark points for further processing. One can also use the tpsUtil program to create a sliders file to define which points are landmarks or semilandmarks. In the tps file they are all just landmark points.

2.9 Using the curves tool

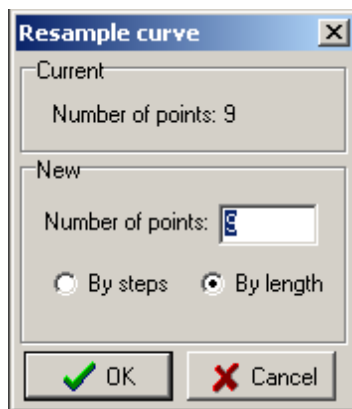
The curves tool  on the toolbar is usually used to insert points along the outline of a structure by hand rather than automatically using the outline tool. It displays a pencil cursor that you can use to draw a connected line segment each time the left mouse button is clicked. Press the right mouse button, double-click, or click on the Edit mode button on the toolbar to start a new curve.

In edit mode, moving the cursor over the curve will select it and the number of points will be displayed on the status panel. If one right-clicks on the curve a context menu will be displayed that will allow one to: delete the entire curve, delete a selected point (if the cursor was on a curve point), resample the curve, switch back to digitize landmark mode, or just cancel the context menu. If Resample is selected, then a window will be opened that displays the current number of points on the selected curve and allows one to specify a new number. If the "By steps" option is selected then the new number must be less than the existing number. Points will be deleted to achieve the desired number of points. Usually one will wish to use the "By length" option. With this option the new number of points can be less than, equal to, or larger than the existing number of points. The new points will be computed by linear interpolation along the curve. They will be approximately equally spaced (it is difficult to achieve exact equal spacing because deleting points changes the length of the curve when the curve changes shape as a result of the deletion of points). In both cases the minimum number of new points is two.

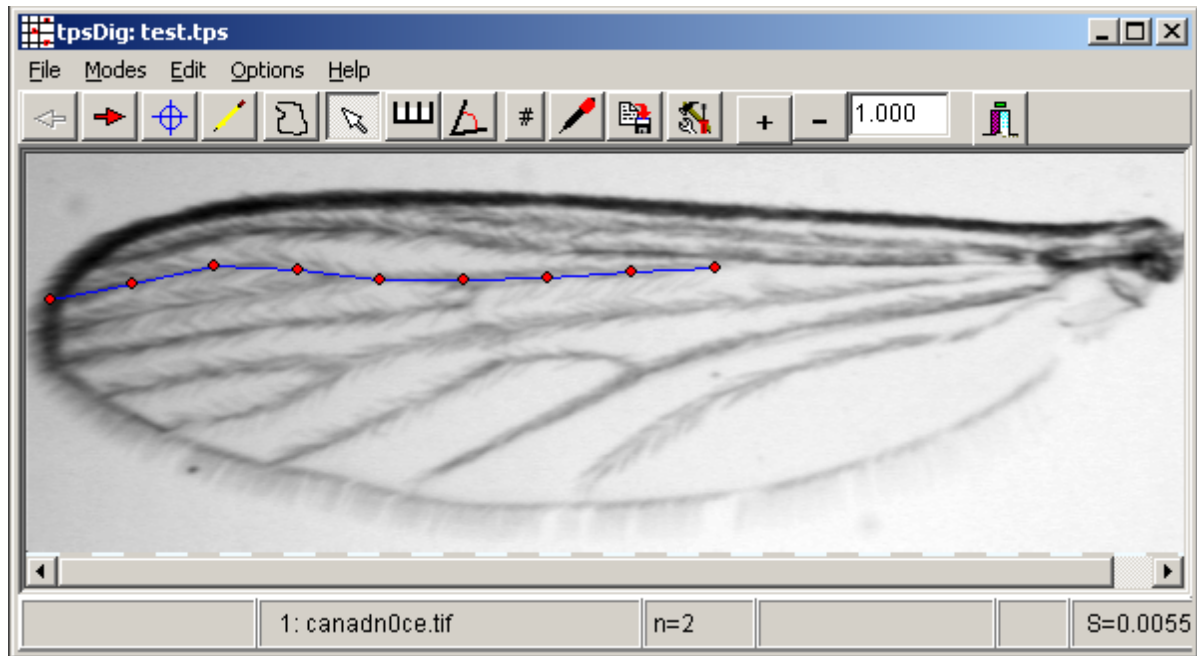
Example of an image with points along a curve:



Resampling dialog:



Result of resampling based on the length of the curve:



Once three or more points have been defined on a curve its enclosed area will be computed and displayed on the status panel at the bottom. This information can be saved to [listing window](#) by clicking on this panel.

Note: on computers with overly responsive mice, one may inadvertently insert multiple points with a single click of the mouse. Displaying the Resample menu will check and eliminate such duplicate points from the selected curve.

Note: other software may not recognize curve points as landmark points. The tpsUtil program has an option to append curve points as landmarks in order after any existing landmarks.

Files

3 Files

3.1 Data file formats

The TPS file format (identified by a file extension of "TPS") is supported. It is a non-standard file format that allows not only the x,y-coordinates of the landmarks but also outlines, names of associated image files, scale factor, and comment fields. Points can also be recorded along background curves to outline the organism. The format is described below. The NTS format is supported for saving (but not for reading) files.

TPS format

There are keywords and parameters for the number of landmarks, the number of background curves, and for the number of points in each curve. The coordinates are given as a pair of x,y-coordinates on each line with at least one blank separating them. An ID code, comment, or numerical codes may optionally be given after special keywords. See the example given below and the sample files included with the program. The data file consists of two or more specimens to be analyzed (all of which must all be placed in the same file one after the other). They must all have the same number of landmarks. If images are provided then the coordinates must be given in pixel units in order to align the landmarks with their positions on the images. Images must be provided in order to use the image unwarping and image averaging features of the program.

The following keywords are defined: LM, LM3, CURVES, POINTS, OUTLINES, CHAIN, RADII, RADIIXY, IMAGE, ID, COMMENT, SCALE, and VARIABLES.



Note: the keywords *do not* need to be capitalized. It was done here just to make them stand out.

Initially, an "empty" input TPS file simply provides a list of the names of the image files. For example

```
LM=0
IMAGE=test1.tif
LM=0
IMAGE=test2.tif
```

After digitization the file is expanded to include the coordinates of the landmarks and, optionally, curves, comments, etc. If the image is enhanced it can be stored under a new name and the TPS file will use the new file name (which can also be of a different graphic file format). An example is shown below with explanatory comments to the right (*not* included the file).

```
LM=4           ← number of landmarks, label for specimen
10 25          ← x,y coordinates
1 50 "
5 22 "
22 45         "
CURVES=2       ← number of hand-drawn background curves
POINTS=4       ← number of points in first curve
0 20          ← x,y coordinates of first curve
5 25 "
```

```

30 40      "
35 50      "
POINTS=4   ← number of points in second curve
50 50      ← x,y-coordinates of second curve
40 30      "
30 15      "
25 0  "
IMAGE=test1.BMP ← Name of file giving an updated image
ID=species1 ← any identification code
COMMENT=female ← a comment
SCALE=0.0054 ← scale factor to convert pixels to user units
OUTLINES=4 ← -2 outlines follow
CHAIN=20 ← stored as an 8-direction chain code with 20 steps
58 23      ← coordinates of the first point
0233344443665666554 ← chain coded outline
POINTS=5 ← next outline given using 5 coordinates
24 55      ← x,y coordinates of points around outline
33 75
45 65
32 45
22 31
RADIIXY=5 ← 5 radii as x,y coordinates
65 79
98 69
110 72
112 88
98 85
RADII=6 ← 6 radii at equal angles from centroid
62 78 100.286 78.889 ← start x,y and coordinates of centroid
38.297 11.214 9.741 ← radii
24.739 10.258 7.464

```

Any **missing landmarks** will assigned the coordinates -1, -1. Note that at present the other programs in the tps series will not recognize missing landmarks - though eventually they should.



Note: the LM= keyword must be given first in the file even it is just "LM=0".. The others can be given in any order.

If the keyword RADII=*n* is used then the outline is stored as *n* equally-spaced radii from the centroid of the outline. If the number of points is entered as a negative number then the radii are assumed to have been captured in a clockwise direction. The next line must contain the x1,y1 coordinates of the starting point followed by the x,y coordinates of the centroid of the outline. Subsequent lines contain the *n* values of the radii.

If the keyword RADIIXY=*n* is used then the *n* radii are entered as x,y coordinate of their endpoints.

Such an outline must be single-valued. Points will be deleted from the outline in order to achieve this.

The following image file formats are supported: BMP, GIF, JPG, PCX, PNG, and TIF. Files of each type must use these codes as extensions to their file names.



The AVI and MOV multimedia files are also supported by tpsDig but not in a tps file. You must load the AVI or MOV files directly so that the program can extract individual frames to be digitized.

3.2 Sample data files

There are several sample data files on the distribution disk:

1. `test.tps` is a sample TPS file. It is an initial file and is intended only to provide a list of the image files to be processed.
2. There are two image files `canadn0c.tif` and `canadn1.tif`. These are both images of the left wing of female *Aedes canadensis*.

These test files can be used to experiment with both image enhancement (both images are rather dark low contrast images) and with recording of landmarks (try using the branch points of the veins and their points of intersection with the wing margin).

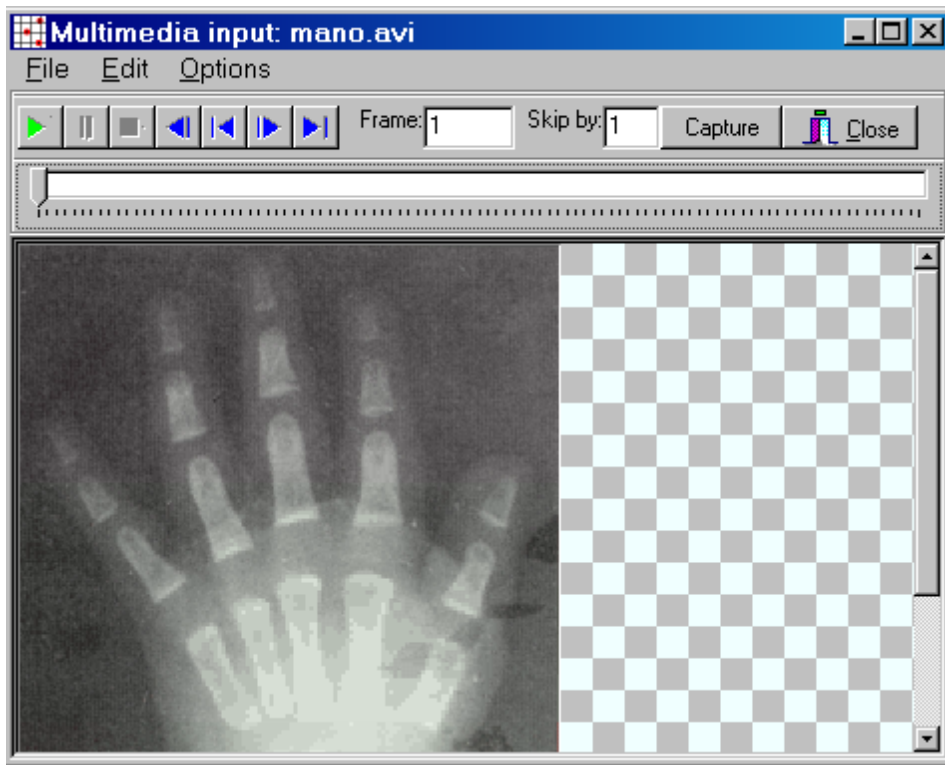
3.3 Graphic file formats

The following types of standard image graphic file formats are supported: TIFF Bitmap (TIF;TIFF;FAX;G3N;G3F), CompuServe Bitmap (GIF), JPEG Bitmap (JPG;JPEG;JPE), PaintBrush (PCX), Windows Bitmap (BMP;DIB;RLE), Portable Network Graphics (PNG), Windows Metafile (WMF), Enhanced Windows Metafile (EMF), Targa Bitmap (TGA;TARGA;VDA;ICB;VST;PIX), Portable Pixmap, GrayMap, BitMap (PXM;PPM;PGM;PBM), Wireless Bitmap (WBMP), JPEG2000 (JP2), JPEG2000 Code Stream (J2K;JPC;J2C), and Video for Windows (AVI).

Note: some TIF files use a special compression that this program may not be able to read.

3.4 Multimedia input window

This window displays frames from an AVI or MOV file and transfers selected frames to the main tpsDig window.



The VCR type controls enable one to move forward and backward through a file to select the desired frame (the frame number will be displayed). The progress bar shows the current position in the file.



The buttons above correspond to Play, Pause, Stop, rewind to beginning, backup frames (by the step size), advance frame (by the step size), and move to the end of the file. The frame number displays the current frame number. The Skip by window allows one to choose the increment for advancing through the file (may be useful when there are many frames).

Click on the "Capture" button to transfer the current image to the Main window. Equivalently, you can click on the right arrow button in the main window to capture the currently displayed frame. Before the image will be transferred to the Main window you will be prompted for a file name for the image currently displayed in the main window if the "Query save image?" option is checked.

The name of the file and the current frame number will be stored in the [comments field](#) when a frame is captured. This information will be saved with the TPS file.



Note: make sure that this window is fully open and clear of any overlapping windows before you click on the Capture button or else parts of these other windows may be included in the image.

Support

4 Support

4.1 Technical support



For help with this program contact

F. James Rohlf, Department of Ecology and Evolution and Department of Anthropology, Stony Brook University, Stony Brook, NY 11794-4364.

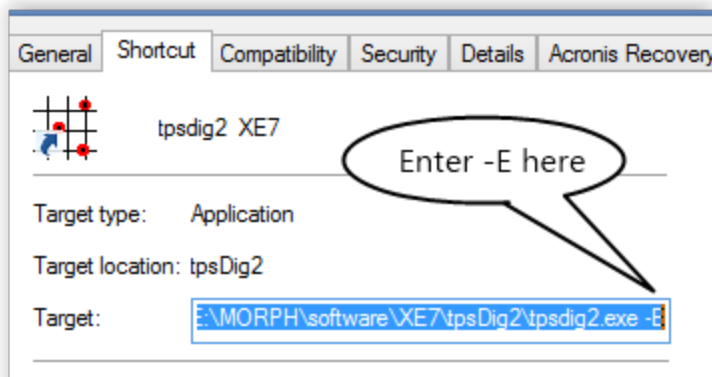
e-mail: f.james.rohlf@stonybrook.edu

Announcements of bug fixes and other significant changes in the program will be distributed via the morphmet listserver at morphmet@morphometrics.org. You can also get help with questions about the uses of this software. This list is maintained by Dr. Dennis Slice (e-mail: dslice@morphometrics.org).

4.2 Installing tpsDig2

On some computers there is a problem of where the INI file should be stored. On older software this was usually in the same folder as the executable program file. A disadvantage of this is that on some networked computer labs users are not permitted to write to such folders. The new standard location is in the user's documents folder. This program will attempt to write the INI file there for all versions of Windows later than Windows XP. Using the documents folder has the advantage that different users of the same computer will have their own INI files with their own preferences.

However, some computers are configured to not permit that even though they are using Windows 7 or 8. As a work-around, one can add the -E parameter to the program when it is executed. It will then be forced to use the program's folder as in XP. To do this one will have to edit the Windows shortcut icon for this program. To do this right-click on the icon for tpsDig2 and select "Properties" from this context menu. Edit the Target field by adding -E to the end of the line (be sure to leave at least one blank space between tpsdig2.exe and -E. The screenshot below shows an example (note that the path before tpsdig2.exe will be different on your computer).



4.3 Changes

The following are the more major changes have been made:

Version 2.28: Fixed the copy and save screen operations so both the image and any annotations are also included. Added option to change the color of the "rubber band line" used for making measurements (helpful when working with dark images), and added an option to select whether the sizes of the landmark points and their labels should be in image pixels or screen pixels (this makes a difference when working with very large images).

Version 2.26: Added option to allow the current image zoom factor to be applied to the next specimen. Also allowed the go to specimen window to accept up to 99999 specimens.

Version 2.25: Fixed several problems that occurred when no specimens had been loaded. Added option to "bee" when a landmark has been added. Allowed landmarks to be added after a curve had been resampled.

Version 2.19: Recompiled using Delphi XE8 and created both 32 bit and 64 bit versions. Some relatively minor changes were also made and the help file was also updated.

Version 2.12: Fixed problems with resampling curves, saving changed images, and setting a default scale factor.

Version 2.11: Fixed a problem in recording measurements to the listing file. Added ability to change the color of the line used for measurements.

Version 2.09: Added ability to resample curves drawn with the Curves tool. A problem with setting the scale factor was also fixed.

Version 2.08: A series of minor updates including: displaying in the status window just the file name rather than the full path name of the image and adding an option to use a right-click to toggle between edit and landmark modes.

Version 2.05: Various minor problems fixed. Most recent was to improve the saving of measurements as "variables" that can be converted into a data matrix using the tpsUtil program.

Version 2.00: Major upgrade! The image display and manipulation routines were replaced which required many changes in the program. Set scale feature moved to the Image Tools window.

Version 1.40: Added option to specify whether outlines are to be traced in a clockwise or counter clockwise direction.

Version 1.34: Added areas in status panel to show total number of specimens in the file and the scale factor (if any) for the current specimen.

Version 1.30: Allows outlining and viewing of thresholds at different zoom levels. Fixed a problem in the "template" mode of digitizing (when the second point moved differed a lot in the x-coordinate the landmarks did not align properly).

Version 1.28: Added computation of outline perimeter. Fixed some problems with measurement mode when a scale was set.

Version 1.26: Added a linear measurement mode. Also fixed a problem when both outlines and landmarks are recorded for an image.

Version 1.22: Added computation of enclosed area of curves drawn when in curves mode (pencil tool). The scale factor will be applied if it has been defined. Added additional ways in which outlines can be stored. Fixed a problem that could cause the image and the landmarks to be greatly out of alignment in large image files.

- Version 1.20:** Allow zoom level to remain the same after image operations such as contrast enhancement, B&W invert, etc. Allow image cropping to be performed while image is zoomed. Added a crop mode cursor. Removed an unnecessary warning message about data not having been saved. Checks landmark coordinates in input data file to make sure they are within the image.
- Version 1.18:** Fixed a number of small problems in the program. Made corrections and additions to help file and its index.
- Version 1.17:** Fixed several awkward problems with the user interface. The program should now be easier to use. Added the following features: load file from the command line (and hence can be placed in the "send to" menu, load file dropped onto form, profile plot can now average brightness over several pixels, sample line width and color now shown on the Paint page of the Image toolbox. When moving from image to image the current zoom setting is now retained.
- Version 1.16:** Added support for input from AVI and MOV multimedia files. Added an Append TPS file menu option and a paint mode in which one can draw directly on an image. Added a profile plot to display image brightness along a horizontal or vertical line. Implemented WinHelp2000 style help file.
- Version 1.15:** Increased the maximum number of landmarks to 1000 (useful for some non-morphometric applications of the program).
- Version 1.12:** Added ability to compute areas corresponding to either light & dark pixels or to the region enclosed by an outline.
- Version 1.11:** Added buttons to reflect an image from left to right or from top to bottom. Added a menu item to allow the saving of the data using the NTS format. Added the use of the left and right arrow cursor keys as equivalent to clicking on the left and right arrow buttons on the toolbar. Fixed some bugs resulting from the conversion to a 32 bit program.
- Version 1.10:** Converted program to a 32 bit Windows 95/NT program. Added an append data file option.
- Version 1.08:** Several important small changes to eliminate problems produced by the inclusion of outlines in the previous version.
- Version 1.07:** Major change is the addition of automatic capture of image [outlines](#) (either as coordinates or as chain codes). Added Set_scale_window for each image. Added a "Clear data" item in the file menu. This can be used to clear all information from all specimens so that you can start over. Made changes to prevent points from being saved whose coordinates are not on the image. Reorganized the Image Toolbox window. Changed x,y coordinates displayed on the screen to match the digitized positions even when the image is zoomed (the y-coordinate is somewhat arbitrary when there is no image).
- Version 1.06:** Various minor changes.
- Version 1.05:** Added zooming of images. Fixed some other problems with reading files.
- Version 1.04:** Added scroll bars so that larger images could be used. Fixed problem with reading an image directly (rather than via a tps file).
- Version 1.03:** Alternative digitizing cursors were added. Print quality was improved and a choice was given between printing just the image or the image as seen on the screen with the landmarks. The maximum numbers of landmarks, curves, and points along curves was increased. The method for handling error conditions was improved.
- Version 1.01:** The image enhancement operations were generalized so that they would work with graphic adapters displaying more than 256 colors. Other small changes were made to the program and this help file.

4.4 Updates

Updates of this program will be made available from the `morphmet` directory of the server at `Life.Bio.SUNYSB.edu`. The most convenient way to access this server is via the morphometrics WWW home page at <http://Life.Bio.SUNYSB.edu/morph/morph.html> (this will also give you a chance to see what other morphometric software is currently available).

Note: while not always necessary, it is good idea to uninstall the old version before installing the new one. None of your data files will be lost or changed when uninstalling the program.

Announcements of bug fixes and other significant changes in the program will be distributed via the `morphmet` listserver at `morphmet@wfubmc.edu`. This list is maintained by Dr. Dennis Slice (e-mail: dslice@morphometrics.org). A link to the instructions is given at <http://www.morphometrics.org/home/morphmet>.

4.5 Credits

This software was developed by

F. James Rohlf, Department of Ecology and Evolution and Department of Anthropology, Stony Brook University, Stony Brook, NY 11794-4364.

e-mail: f.james.rohlf@stonybrook.edu

Its development was supported in part by a grant (DEB 93-17572) to F. James Rohlf from the Systematic Biology Program of the National Science Foundation and by a grant (IBN-9728160) to F. James Rohlf and Dennis E. Slice from the Ecological and Evolutionary Physiology Program of the National Science Foundation.

Dean Adams helped with some of the early "crash testing" of the program and proofing of the help file. Dennis Slice provided some technical advice and Leslie Marcus gave many comments of the operation of the program. The comments by participants at the various morphometric workshops were also very helpful. Many others have sent me suggestions via e-mail. All of this help is greatly appreciated.

To cite the use of this software in a publication, please list it in your bibliography in the following form (inserting, of course, the appropriate year and version number for your copy of the software):

Rohlf, F. J. 2005. tpsDig, digitize landmarks and outlines, version 2.05. Department of Ecology and Evolution, State University of New York at Stony Brook.

One can cite the entire tps series of software as follows:

Rohlf F.J. 2015. The tps series of software. *Hystrix, the Italian Journal of Mammalogy*, 26:1-4.

The paper can also be downloaded from the journal at:

<http://www.italian-journal-of-mammalogy.it/>

4.6 Program limitations

At present the program has these limits:

| <u>Parameter</u> | <u>Limit</u> |
|-------------------------|---------------------|
| Dimensions, k | 2 |
| Landmarks, p | 1000 |
| Background curves | 25 |
| Points in each curve | 150 |
| Points in each outline | 10,000 |
| Undo/redo stack | 9 |

There is no defined limit to the number of specimens or the size of the image files, but at some point the program will run out of memory. While only the image for the current specimen is stored in memory, all coordinates are kept in memory until the file is saved. Except for the number of dimensions, the limits can easily be changed. [Technical support](#) is available if you have special requirements.

Another limitation is due to the resolution and color depth of the graphics being used. Higher resolution monitors (e.g., 1024x768) are more convenient than lower resolutions. This software is not designed to work on systems that cannot display at least 256 colors. Images that require many colors or many shades of gray often do not display properly on systems set to use just 256 colors. The problem is that even though tpsDig correctly computes the transformed image, Windows may redefine some of the colors because it needs them to display other information on the screen. The colors of one window may change when you highlight another window. The solution is to set your graphics adapter for HiColor (16 bit, 32K colors) or TrueColor (24 bit, 16M colors) modes. Unfortunately, these require additional RAM on the graphics adapter. As a result you may be forced to use a lower resolution if you have an older PC.

Images can be digitized directly from TWAIN compatible scanners. Video sources compatible with Microsoft TV in a Window can also be used.

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5 Glossary

5.1 Glossary

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