IDL Tutorial

Working with Images

The IDL Intelligent Tools (iTools)

The IDL Intelligent Tools (**iTools**) are a set of interactive utilities that combine data analysis and visualization with the ability to produce presentation quality graphics. The iTools allow users to continue to benefit from the control of a programming language, while enjoying the convenience of a point-and-click environment. There are 7 primary iTool utilities built into the IDL software package. Each of these seven tools is designed around a specific data or visualization type :

- Two and three dimensional plots (line, scatter, polar, and histogram style)
- Surface representations
- Contours
- Image displays
- Mapping
- Two dimensional vector flow fields
- Volume visualizations

The iTools system is built upon an **object-oriented** component framework architecture that is actually comprised of only a single tool, which adapts to handle the data that the user passes to it. The pre-built *iPlot*, *iSurface*, *iContour*, *iMap*, *iImage*, *iVector* and *iVolume* procedures are simply shortcut configurations that facilitate ad hoc data analysis and visualization. Each pre-built tool encapsulates the functionality (data operations, display manipulations, visualization types, etc.) required to handle its specific data type. However, users are not constrained to work with a single data or visualization type within any given tool. Instead, using the iTools system a user can combine multiple dataset visualization types into a single tool creating a hybrid that can provide complex, composite visualizations.

Image Display, Enhancement, and Regions of Interest

The IDL *iImage* tool can be used to display gridded 2-Dimensional arrays of data in image form. The *iImage* utility has built-in support for the input of images in BMP, DICOM, GIF, JPEG, JPEG2000, PICT, PNG, and TIFF formats. Once an image is loaded into the *iImage* tool there are several options for visualizing, manipulating, and processing the imagery. Furthermore, the library of IDL routines contains a rich suite of image processing algorithms.

In the following exercise, the image data from the example data file "*MRI.dcm*" will be input into the *iImage* utility. This example data file is located in the "*data*" subfolder.

The file "*MRI.dcm*" is in DICOM format, which is the industry standard for storing imagery and diagnostic patient information in the radiology community. This file contains a grayscale (black-and-white) image of a MRI exam involving a single slice through a human brain. The MRI image can be loaded into the *iImage* utility using the following steps :

1. At the IDL> command prompt execute the statement "*iImage*".

2. Click on the open file ☞ button on the toolbar of the *IDL iImage* window.

3. Select the "*MRI.dcm*" file and hit "*Open*". An image graphical object will be automatically inserted into the utility.

Along the right-hand side of the *iImage* utility is a panel that is not present on the other iTools utilities. This panel contains cursor query, histogram manipulation, and ROIs (Regions Of Interest) tools specific to the image graphical object.

4. While the image object is selected and the iTool is in Select/Translate arrow mode, move the mouse cursor over the image and watch the "Pixel Location:" and "Pixel Value:" fields update.

The origin location for the image (0,0) is considered to be the pixel in the lower-left hand corner. Within the "Pixel Value:" field there is actually 2 numbers displayed: the first being the actual image data pixel value, and the second within parentheses is the scaled display value [Fig. 1]. Since the computer monitor can only display 256 (or sometimes less) levels of discrete brightness for each color channel, all image data is scaled to fit within the range of 0 → 255 automatically by the *iImage* utility if it does not already. The "Min:" and "Max:" fields within the *Image* panel show that the actual data range for this image is 0 → 402, so these image pixel data values must be scaled in a linear fashion to fit within the corresponding display range of 0 → 255.
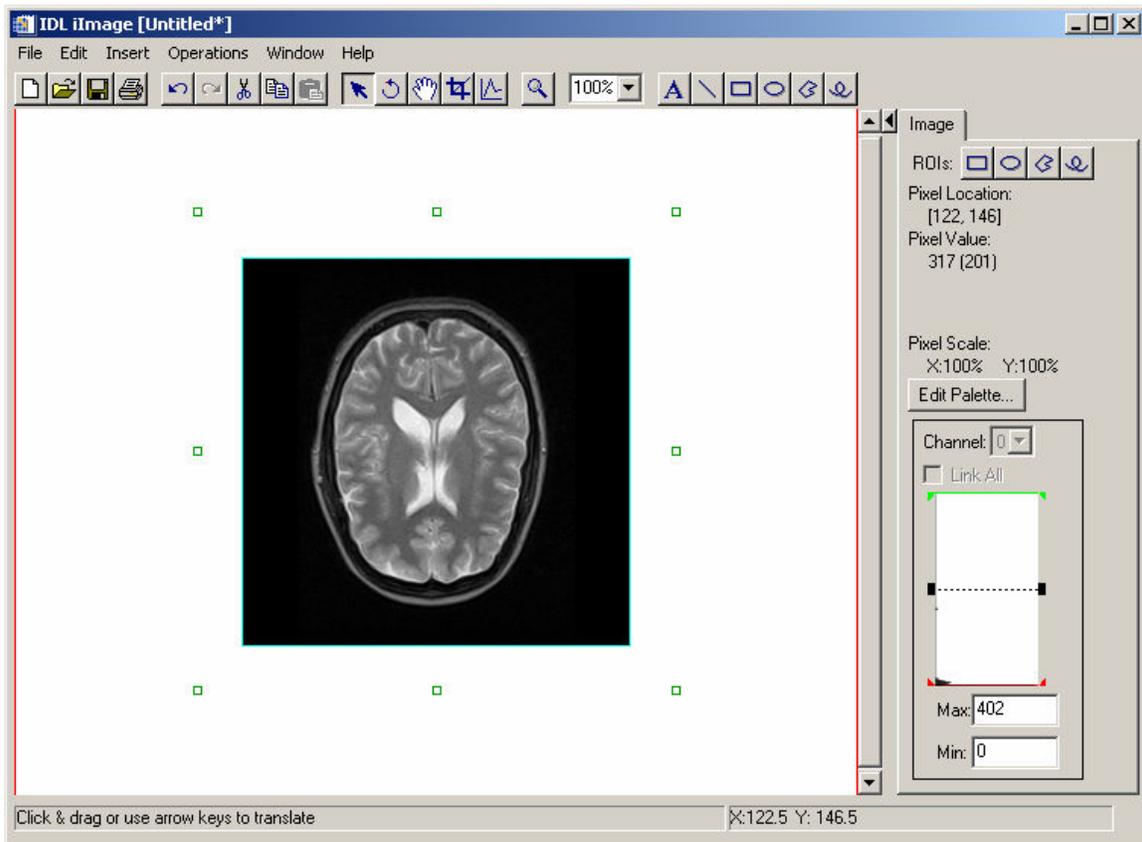
Figure 1: The iImage utility displaying a MRI image of a human brain

The *Image* panel also displays a small **histogram** (density) plot of the pixel data values displayed on its side [Fig. 1]. The histogram plot ranges from the minimum pixel data value on the bottom to the maximum pixel value on the top. Since the current image is dominated by very dark pixels (i.e. the black area around the border), the scaling of this histogram is skewed and difficult to visualize in such a small display window. Fortunately, the iTools system has a built-in operation for creating a separate *iPlot* utility that displays the density distribution for data objects using a histogram plot.

5. Make sure the image object is selected.
6. From the *IDL iImage* window menu system, select "*Operations > Histogram*".

A separate *IDL iPlot* window appears, and the histogram density plot for the image is displayed in a more robust fashion. Notice that most of the pixels in the image (more than 40,000) have a very low (dark) data value.

7. Once finished viewing the image histogram, close the separate *IDL iPlot* window.

The image histogram window within the *Image* panel has 3 horizontal bars that the user can interactively click-and-drag in order to modify the input data range that is used to compute the output scaled image [Fig. 1]. The red bar is used to designate the minimum threshold value, the green bar corresponds to the maximum threshold value, and the black bar in the middle is used to move the current range up and down within the image histogram. In other words, all input image data pixel values that are equal to or less than the current location of the red bar are saturated to an output display value of 0 (black), all input image data pixel values that are equal to or greater than the current location of the green bar are saturated to an output display value of 255 (white), and all of the pixel values in between are scaled in a linear fashion from 1 → 254.

8. Click on the green maximum image stretch bar and move it down within the histogram plot window. Notice how the "Max:" field within the Image panel updates with the selected pixel data value, and the image display is automatically updated based on the stretch modification.
9. Click on the red minimum image stretch bar and move it up within the histogram plot window.
10. Finally, click on the black range location bar and move it up and down to re-position the current image stretch.
11. Once finished experimenting with the histogram manipulation tool, reset the stretch to its original state by moving the green and red bars to the top and bottom of the window, respectively.

The Image panel within the iImage utility also has built-in **regions of interest** (ROI) tools that can be used to specify certain areas within an image for processing and analysis.

12. While the image object is selected, click on the freehand ROI definition button to enter into ROI definition mode.
13. Once the mouse cursor is positioned over the image object it will change to the ROI definition pencil pointer. Click-and-drag with the mouse to draw a

ROI on top of a feature within the MRI image. When the mouse button is released the ROI definition will complete to a solid polygon, and the new ROI will be highlighted with small green boxes.

Once the ROI definition is complete, the object can be resized and moved by clicking on or within the green highlight boxes. Now that a region of interest has been defined, the user can obtain useful information about the image pixels contained within the region such as statistics :

14. While the ROI object is highlighted, select "*Operations > Statistics…*" from the menu system.

A separate dialog entitled "*Display statistics for the selected item*" will appear, which lists useful statistical information on the image data contained within the region of interest [Fig. 2].

Note: The exact statistical information that is reported will vary from what appears in Fig. 2 since the ROI is drawn in an arbitrary fashion.
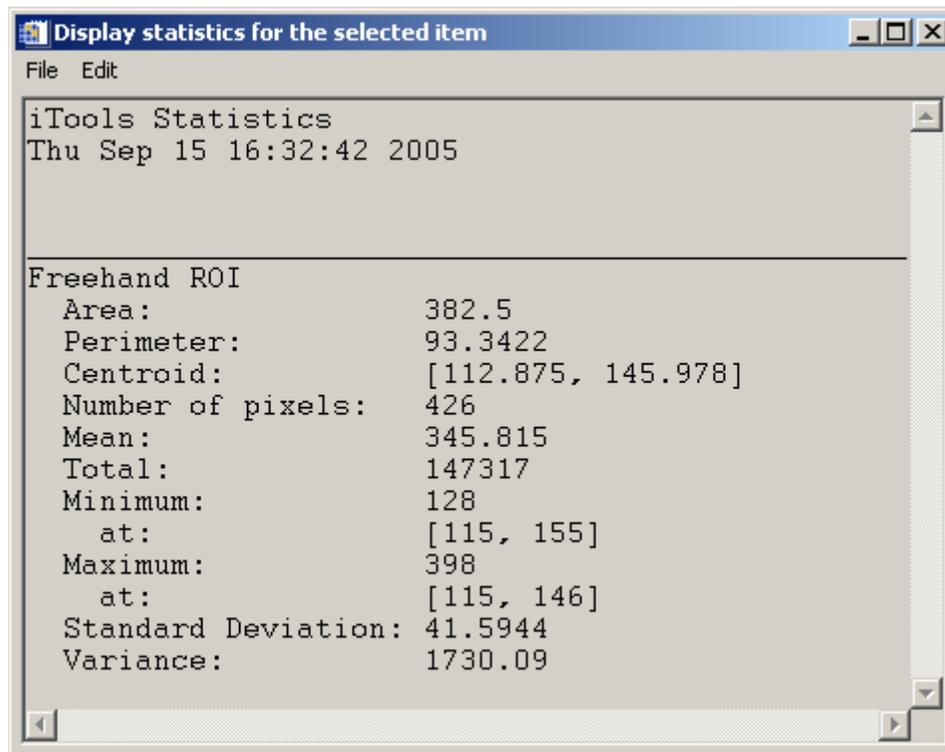
Figure 2: Statistical information on the image data within the defined ROI

15. Once finished viewing the statistical information, close the "*Display statistics for the selected item*" dialog.
16. While the ROI object is selected and highlighted, right-click on it and select "*Delete*" in order to remove it from the current visualization.

Color Palettes, Filtering, and Morphology

Currently the MRI image is displayed with a simple grayscale color palette that was read-in from the DICOM file on disk. This palette displays the image in a very simple black-and-white fashion. In addition to the standard grayscale color palette, IDL also has a number of pre-built color tables that can be applied to singe channel images in order to give them a colored appearance.

1. Select the image, then press the "*Edit Palette…*" button on the *Image* panel.
2. A separate *Palette Editor* dialog will appear. Within this window press the "*Load Predefined…*" droplist and select the "*BLUE/GREEN/RED/YELLOW*" color palette.
3. Press "*OK*" to dismiss the *Palette Editor* dialog.

Instead of displaying the image with the input Black → Gray → White color palette, the *IDL iImage* utility is now applying the selected color table and displaying the image brightness values through the color range of Black → Blue → Green → Red → Yellow. This allows the user to visualize the features within the image in color and can help highlight aspects of the image that were not readily visible in standard black-and-white mode.

4. Experiment with moving the green, red, and black stretch manipulation bars on the image histogram once again to see the effect the new color palette has on the image display.
5. Once finished experimenting with the histogram manipulation tool, reset the stretch to its original state by moving the green and red bars to the top and bottom of the window, respectively.

At this point it may be useful to insert a colorbar into the current visualization so the user can see how the input image pixel data range maps to the colors that are displayed.

6. Make sure the image object is selected, and from the menu system select "*Insert > Colorbar*" [Fig. 3].
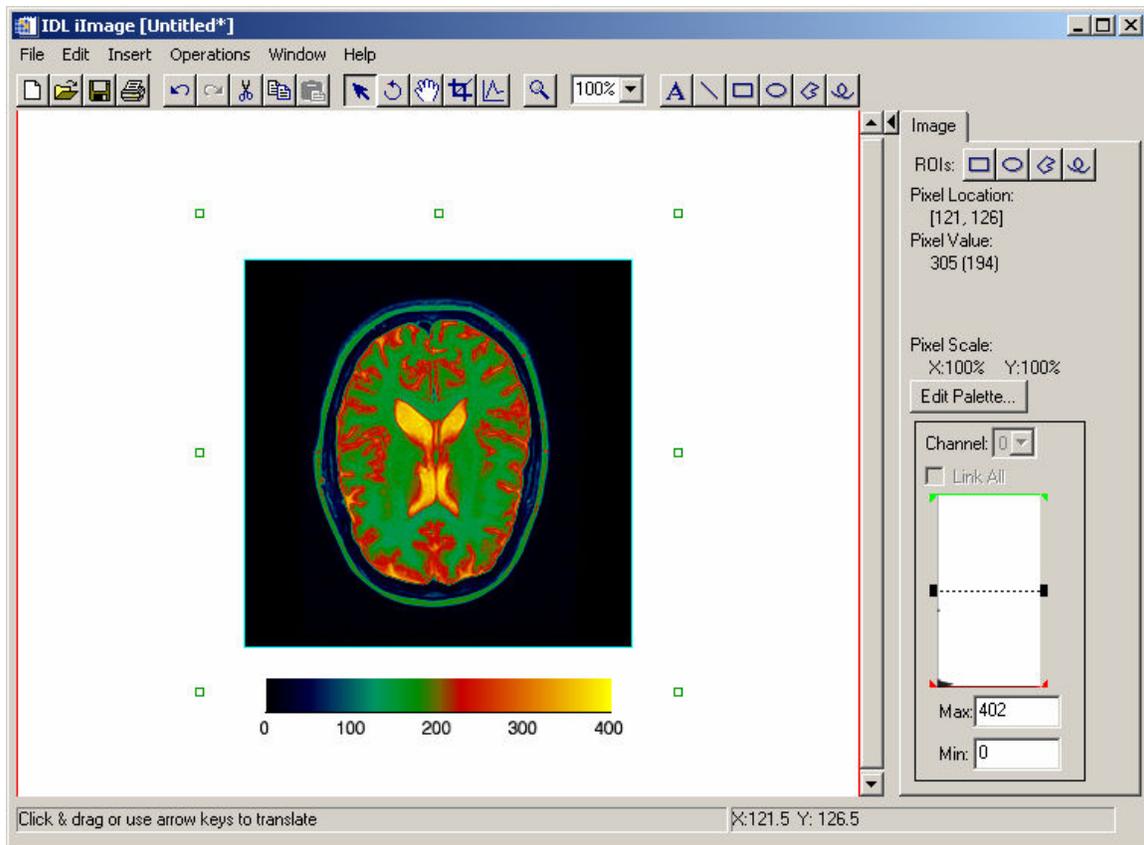
Figure 3: The MRI image displayed with a color palette

In addition to the extraction of statistics, there are a number of other standard image processing tools found within the *Operations* menu. The operations available for an image object include the ability to apply a filter, highlight shapes using morphological operators, and rotate or flip the image.

7. Make sure the image object is highlighted and select "*Operations > Filter > Smooth*" from the menu system.
8. Within the *Smooth* dialog, leave all parameters set to their default values and simply press the "*OK*" button.

This operation will apply a smoothing image filter, which helps to remove unwanted noise using a weighted average. Notice how the image histogram and colorbar automatically update based on the image that is returned from this operation.

9. Select "*Operations > Filter > Sobel Filter*" from the menu system.

The Sobel filter operation uses the Sobel edge enhancement algorithm to detect and highlight edges within the image.

10. Finally, select "*Operations > Morph > Morph Open*" from the menu system.
11. Within the *Morph Open* dialog, leave all parameters set to their default values and simply press the "*OK*" button.

The opening morphological operator removes noise from an image while maintaining the overall sizes of objects in the foreground. The resulting visualization should look similar to Fig. 4.
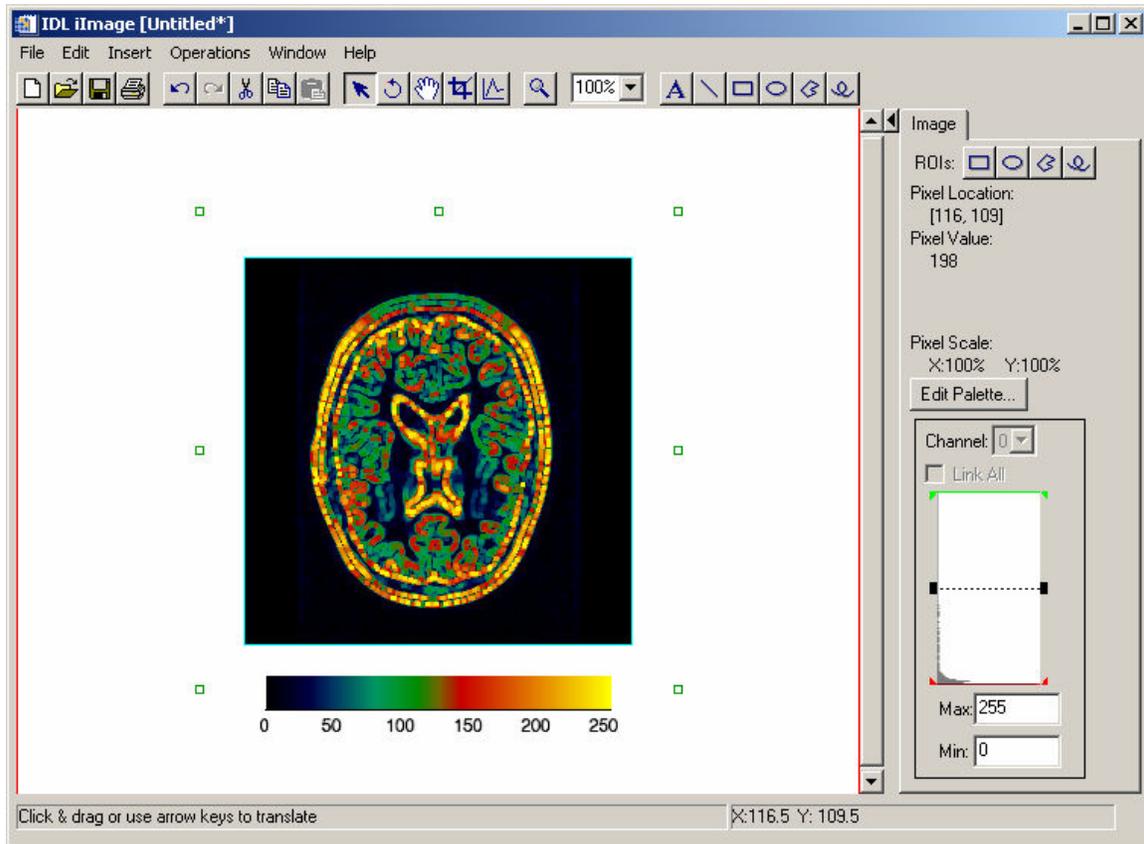
Figure 4: The result of applying Smooth, Sobel and Morph Open operations

12. Once finished viewing the MRI image visualization, close the *IDL iImage* window.

Line Profiles, Contouring, and Advanced Processing

In the following exercise, the image data from the example data file "*nebula.jpg*" will be input into the *iImage* utility. This example data file is located in the "*data*" subfolder.

The file is in JPEG format and contains an image of the famous Ring Nebula taken by the Hubble Space Telescope. In contrast to the single channel MRI image used in the last exercise, this dataset is a 3 channel (Red, Green, Blue) 24-bit true color image. In this case, the three color channels are displayed together in order to visualize the color image. Use the following steps to load the "*Nebula.jpg*" image into a new *iImage* utility :

1. IDL> iImage

2. Click on the open file ![icon] button on the toolbar of the *IDL iImage* window.
3. Select the "*Nebula.jpg*" file and press "*Open*".

The color image be automatically displayed within the *IDL iImage* window.

4. Move the mouse cursor over the image and notice how the "Pixel Value:" field in the *Image* panel is now reporting 3 pixel values: one each for the R (red), G (green), and B (blue) image channels that are combined together to make the color display.

In this case, the image data values already fall within the display range of 0 → 255, so no scaling is needed.

The *iImage* utility has a built-in line profile tool that will plot image pixel values along a user-defined transect. This tool will automatically launch a secondary *iPlot* utility containing line plots for the pixel values along the selected line for each of the three red, green, and blue image channels.

5. While the image object is selected, click on the line profile ![icon] button on the toolbar.

Once the mouse cursor is positioned over the image object it will change to the line profile pointer. In order to define a line profile, the user must left-click at the desired starting location for the transect, hold down the mouse button, drag to the desired ending location for the transect, and release the mouse button in order to complete the profile. Once this is accomplished a separate *iPlot* utility will be launched containing the 3 line profiles (one for each color channel).

6. Using the mouse, click-and-drag from the upper-right hand corner of the image to the lower-left hand corner.

The resulting *IDL Line Profile* window should look similar to Fig. 5.
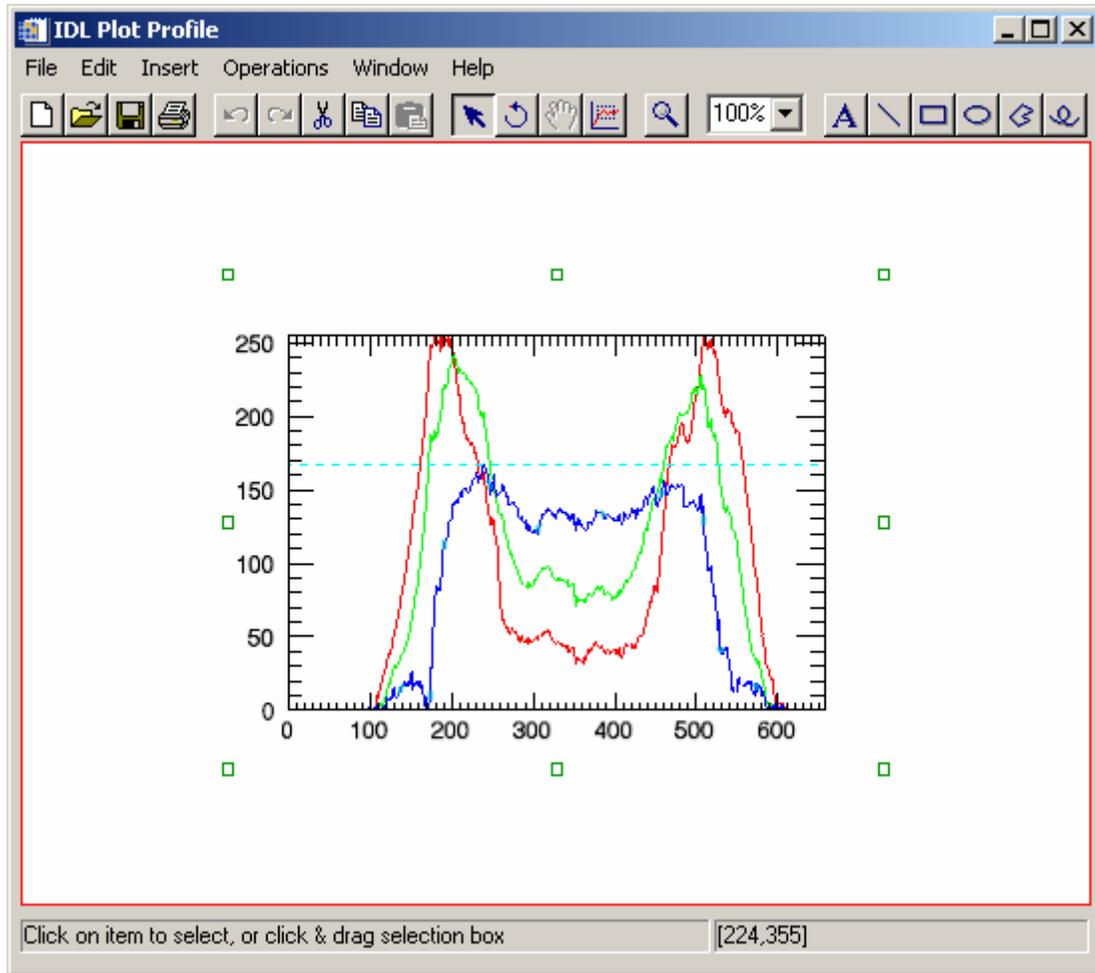
Figure 5: Line profiles extracted from the color JPEG image

7. Once finished viewing the line profiles, close the *IDL Line Profile* window.
8. To remove the line from the current visualization, click on it and press the *Delete* key on the keyboard.

Since image data is actually a gridded 2-Dimensional array of pixel values, it can also be visualized using some of the other graphical objects available in the iTools system. For example, it is quite easy to insert a contour plot into the existing utility in order to make a composite visualization.

9. Make sure the image object is selected.
10. From the menu system, select "*Operations > Contour*".
11. Within the Contour dialog box, change the "Number of levels" parameter to "*10*".
12. Press the "*OK*" button to dismiss the *Contour* dialog box.
13. Select "*Window > Visualization Browser…*" to view the property sheet for the new contour object.
14. Within the *Visualization Browser* window, make sure the contour object is selected, click on the box to the right of the "Contour level properties" item, and select "*Edit…*".

15. Within the first "All Levels" column, change the "Color" property to bright green and hit "*OK*".
16. Close the *Visualization Browser* window.

The resulting visualization should look similar to Fig. 6.
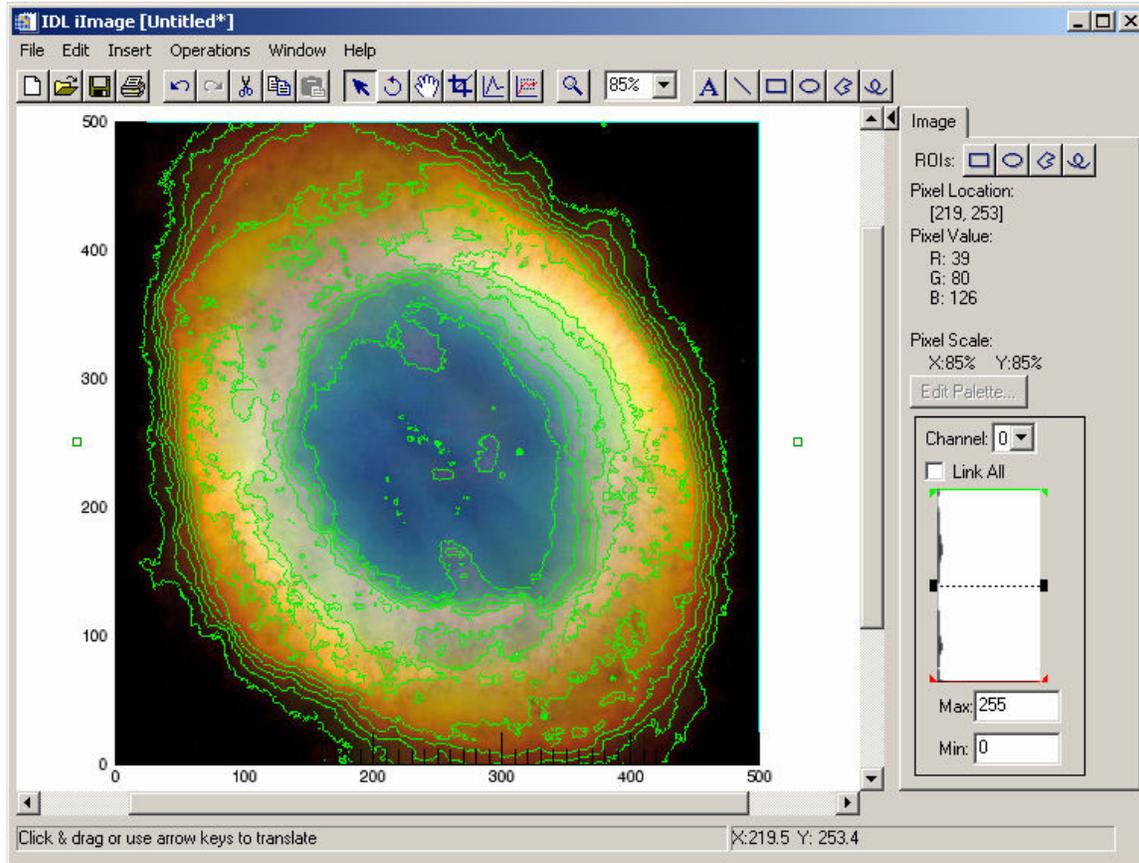
Figure 6: Contour map overlaid on top of the image display

In addition to the analysis capabilities exposed within the iTools system under the *Operations* menu, the IDL library includes hundreds of routines that provide advanced processing capabilities. Some of these processing algorithms are very specialized, and it is not appropriate to place an item within the *Operations* menu in the iTools system to run all of these more advanced tools. Fortunately, the iTools system was designed in a manner that allows the user to easily pass data back-and-forth between an iTool utility and the IDL> command prompt.

In the following exercise, the green channel for the current image will be exported from the iImage utility to the IDL> command prompt level within the IDL Development Environment for specialized processing. First, the green channel image will be smoothed using the SMOOTH function in an effort to minimize noise. Then, the *WATERSHED* function from the IDL library will be used to segment the image into watershed regions and their boundaries. The watershed algorithm considers the grayscale image as a surface, where each local minimum can be thought of as the point to which water falling on the surrounding region drains. The boundaries of the watersheds lie on the tops of the ridges. This operator labels each watershed region

with a unique index pixel value, and sets the boundaries to zero so they are readily visible.

17. From the *IDL iImage* window menu system, select "*File > Export…*".
18. In Step 1 of 3 for the *IDL Data Export Wizard*, select "To an IDL Variable" and hit "*Next >>*".
19. In Step 2 of 3, expand the object hierarchy tree until the green image plane "*Channel 1*" can be selected [Fig. 7].

Figure 7: Selecting the green channel image for export to IDL

20. Press "*Next >>*", and within Step 3 of 3 leave the "IDL Variable Name:" field set to the default "*Channel_1*" and hit "*Finish*".
21. Bring-up the IDL Development Environment window so the IDL> command prompt can be accessed. Execute the following statements at the IDL> command prompt.
22. IDL> `HELP, Channel_1`

This will report to the output log that a 2-Dimensional byte array with the same spatial size as the Ring Nebula image loaded into the *iImage* utility now exists within IDL's main memory space :

```
CHANNEL_1       BYTE     = Array[500, 500]
```

This is a duplicate copy of the same data that is stored in the *iImage* utility, so it can be acted upon in a manner independent of the image that is currently being displayed. Now execute the advanced watershed analysis :

23. IDL> `smoothed = SMOOTH (Channel_1, 9, /EDGE_TRUNCATE)`
24. IDL> `segmented = WATERSHED (smoothed, CONNECTIVITY=8)`

Once this is accomplished, a new variable named "*segmented*" exists at the main IDL level which contains the resulting watershed image. This new image can be loaded into the existing *iImage* utility and compared to the original image using the following steps :

25. From the *IDL iImage* menu system, select "*Window > Layout…*". This will bring-up a separate dialog entitled "*Window Layout*" [Fig. 8].
26. Within the *Window Layout* dialog, change the "Columns:" field to "*2*" and hit *Enter* on the keyboard. The *Preview* pane will update to show the new viewplane which will be inserted into the existing *iImage* utility [Fig. 8].
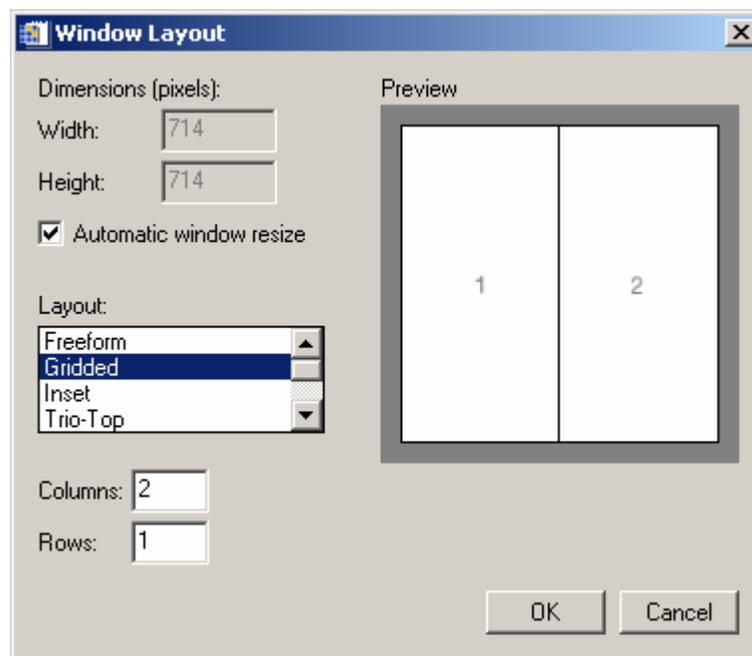
Figure 8: The Window Layout tool within the iTools system

27. Press "*OK*" to dismiss the *Window Layout* dialog.
28. The user will be returned to the *iImage* utility, where the original viewplane will be selected and highlighted with a red border. Click within the new viewplane on the right-hand side in order to designate it as the target for future visualization insertion. Once this is accomplished, the viewplane on the right-hand side of the utility will be outlined in red.
29. Select "*Insert > Visualization…*" from the menu system.
30. Within the *Insert Visualization* dialog, press the "*Import Variable…*" button.
31. Within the *IDL Variable Browser* window, select the "*SEGMENTED*" variable and hit "*OK*".
32. Back within the *Insert Visualization* dialog, click on the new "*SEGMENTED*" data object and use it to define "IMAGEPIXELS" parameter of a new *Image* object visualization.

33. Press "*OK*" to dismiss the *Insert Visualization* dialog and insert the image for the watershed analysis into the second viewplane.

The watershed analysis has segmented the image into discrete regions, which are currently being displayed with the default grayscale color palette. It is more effective to visualize this watershed image using one of IDL's built-in color tables.

34. Select the new watershed segmentation image and press the "*Edit Palette…*" button.
35. Within the Palette Editor dialog click on the "*Load Predefined…*" droplist and select the "*Rainbow + white*" color table.
36. Press "*OK*" to dismiss the *Palette Editor* dialog.

The resulting visualization should look similar to Fig. 9.
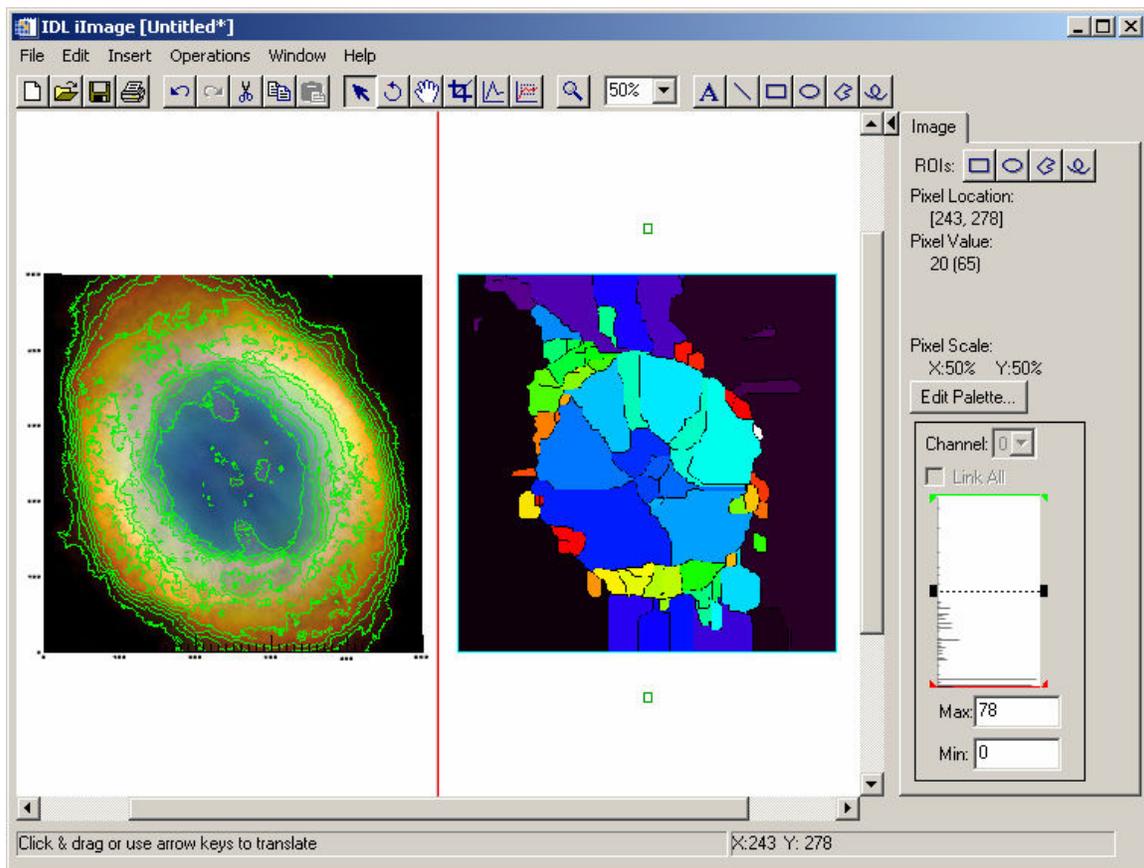
Figure 9: Display of the watershed analysis segmentation image

37. Once finished viewing the two images, close the *IDL iImage* utility.

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