Astral Count
How many small bright objects are out there?

Introduction

This lesson requires ImageJ, available for free download from **http://rsb.info.nih.gov/ij/**. Help files are available at **http://rsb.info.nih.gov/ij/docs/index.html**. For more assistance, *Discovering Image Processing, v.2*, (*DIP*), revised and expanded in 2006, teaches the fundamental concepts of digital image processing and image analysis in ten step-by-step lessons. More information and a free sample *DIP* lesson is available on the Science Approach Web site. Visit **http://www.science-approach.com/**, click **Purchase Products** and navigate to the DIP product page.

Although we won't be tackling the absolute number of stars in the universe, you will be introduced to a technique for counting visible stars on digitized images.

Your mission

Have you ever gazed up at the night-time sky and wondered just how many stars are there?

If so, you're not alone. In the 1780s, disfigured by smallpox and stunted by typhus, Caroline Lucretia Herschel spent most nights crouched over a candle writing notes. Above her, perched on the top of a ladder, her brother William dictated what he saw in the sky as he peered through a telescope the two had built.

In 1781, he was the first to identify the planet Uranus (although he misidentified it at first as a comet). Two years later, Caroline, who had begun her own independent work, spotted three new nebulae and later discovered seven comets and many stars.

In 1787, King George agreed to provide a salary for her, making her the first woman to be a paid scientist.

Your toolkit

Instead of bending over candlelit notes or peering out from a hole in the roof, you will be using ImageJ to view and analyze two images of a night sky. Your task is to

IP Skills

- Image adjustment and thresholding
- Analyze particles

ImageJ Skill Sheets

- Thresholding
- Measuring

Two astronomy 'stars'

William Herschel also discovered infrared light (which he referred to as "calorific" rays), and the European Space Agency named the planned Herschel Space Observatory in his honor. The observatory will collect infrared radiation from distant stars. Lucretia, an asteroid (a type of minor planet) was named for Caroline in 1889.

What's a nebula?

A nebula (plural nebulae) is a hazy cloud where stars are formed.

obtain star counts for these images and to investigate how the numbers are influenced by the limits you set.

Step 1: Gather the data

a. There are two images for this activity, **NorthSky-8bit.tif** and **MilkyNebula-8bit.tif,** inside the folder where you found this lesson PDF.

Step 2: Enhance the image

a. Launch ImageJ. Choose **File > Open**, and navigate to **NorthSky-8bit.tif**.

b. Although it appears to be a solid black box, this image actually shows a night sky in southeastern Arizona during September.

Choose **Image > Adjust > Brightness/Contrast**. Adjust the **Maximum, Minimum, Brightness**, and **Contrast** slider bars until you can see hills, low clouds, and multiple stars.

As you adjust the sliders, notice how the numbers change below the graph.

Qn. 1. *What levels of* **Maximum, Minimum, Brightness**, *and* **Contrast** *are most effective in enhancing this image? (You may use the Data Sheet at the end of the lesson for your answers.)*

c. Choose **Reset** to return **NorthSky-8bit.tif** to its original form.

d. Now choose **Process > Enhance Contrast**, and accept all the defaults in the **Enhance Contrast** window.

Qn. 2. *What happens?*

Step 3: Define a region of interest

a. Your goal is to count stars in a specific region of the sky—one without clouds, hills, or trees. You'll first need to define a region of interest (ROI) that excludes the lower 35-40 percent of the image.

b. Choose the Rectangular Selections tool, ▢, and draw a rectangle starting from (**270, 450**).

Your rectangle should be 140 pixels wide and 180 pixels high, as shown on the next page.

Getting to know the Status Bar

The status bar on the image window shows
- image dimensions (**648 x 486**),
- bit depth (**8-bit**), and
- image size (**307K**).

Inverting the Y coordinates

The Y coordinates in this lesson are expressed starting at the bottom of the image. If they run from 0 at the top to larger values at the bottom, you can invert them by choosing **Analyze > Set Measurements** and then clicking **Invert Y Coordinates**.
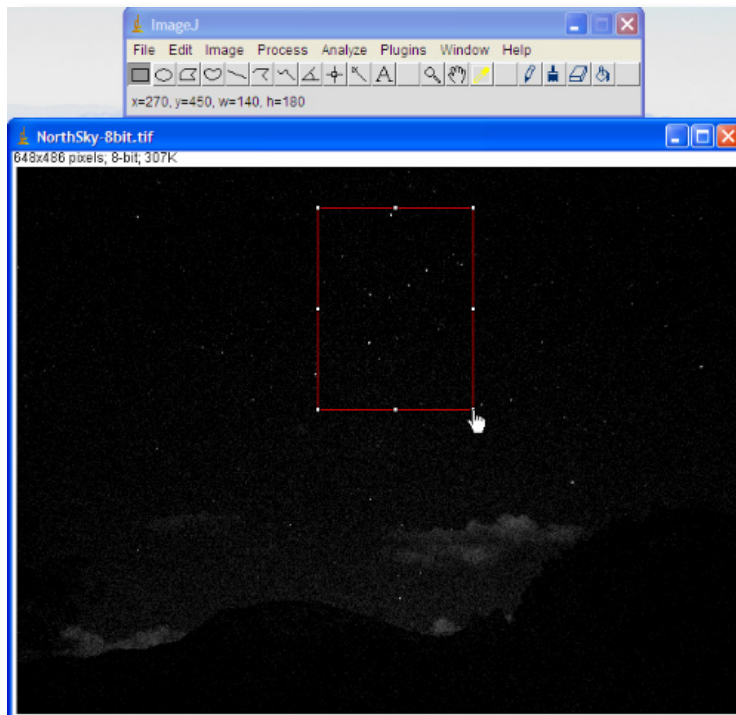
The four brightest stars within your rectangle are part of the constellation Cassiopeia. The fifth is at (**270, 300**), right at the left edge of your ROI.

Step 4: Threshold the image

a. Next, you need to tell ImageJ to set an upper and lower limit for the brightness of the stars you want to count. This process is called **thresholding**.

To threshold the image, choose **Image > Adjust > Threshold**. (For more tips on thresholding, see the **Thresholding Tips** sidebar.)

b. Set the minimum value to **0**, and you'll see that all the image changes to red.

Set it to **1**. Now all pixel values greater than 0 will be colored red.

Designating the appropriate minimum requires some judgment. You will want to highlight meaningful pixel values but not those that may represent noise or artifacts.

c. Try setting the minimum threshold slider to **2** and then **3**.

Qn. 3. *How does the appearance of the image change according to the thresholding?*

Step 5: Count the stars

a. Choose **3** as your minimumthreshold slider.

Now you're ready to count the highlighted pixels. Choose **Analyze > Analyze Particles...** . In the **Analyze Particles...** window, select values as shown below, and click **OK**.
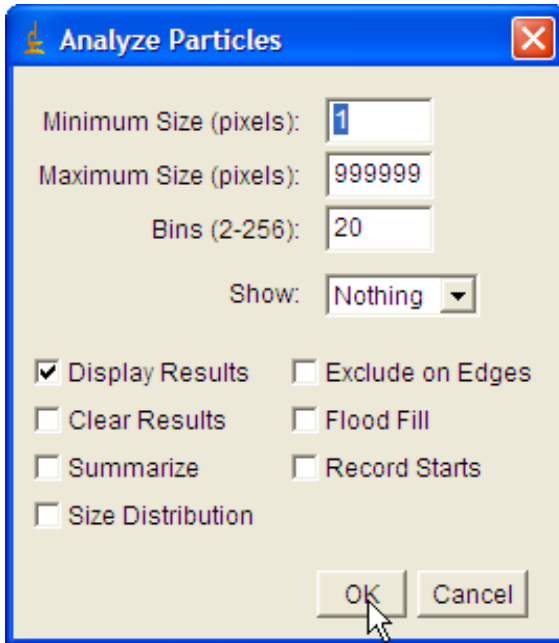
b. When the processing is complete, the **Results** window will appear, which lists data (area, mean pixel value, perimeter) for the objects.

Scroll down to the bottom of the window. The last number indicates the number of stars.

Qn. 4. *How many stars are in your rectangle? Explain how you could tell.*

Step 6: Analyze another image

a. Open the second image, **MilkyNebula.jpg**. This is a larger image of a nebula in the Milky Way, which is the galaxy that contains our solar system.

b. Enhance the image, then define your ROI as a rectangle that again measures 140 x 180 pixels. Your starting point should be (**700, 570**).

c. Threshold the image, again using a maximum of **206** and a minimum of **3**.

d. Count the stars.

Qn. 5. *How many stars are in your rectangle now?*

How many stars are there?

Scientists use several methods to estimate the number of stars in the universe. Stars are not randomly distributed throughout the Universe but are gathered in groups known as galaxies.

1. The number of stars in the Milky Way galaxy has been estimated from the amount of light and mass in the galaxy to be 100 billion (or 10^{11}).
2. The number of galaxies in the Universe has been judged to be 10^{11} - 10^{12}, giving a total number of stars somewhere around 10^{22} or more.
3. An alternative technique to survey the number of visible stars in a strip of sky by viewing the strip with powerful telescopes. came up with a number of 7×10^{22}.

These figures are estimates, but they point out that the number of stars is vast–far more than the number of grains of sand in all the world's beaches and deserts.

Hint ...

To clear the Results table between images, select **Edit > Clear Results** in the Results Window.

Hints ...

Process > Enhance Contrast

Image > Adjust > Threshold...

Analyze > Analyze Particles...

Step 7: Compare two regions within one image

a. Being careful to click inside your ROI, drag the rectangle to (**330, 280**).

b. ImageJ will remember your Threshold settings, so you should be able to choose **Analyze > Analyze Particles...** .

Qn. 6. *How many stars are there in this location?*

The Milky Way is shaped like a thick disk with four long spiralling arms (thus its name of a **spiral galaxy**)—much like a spinning Frisbee with four streamers. Our solar system resides on a tiny part of a very short, fifth arm, that's disconnected.

To give you an idea of scale, while light can travel across our solar system in a day, it would take about 100,000 light years to cross our galaxy!

Further Exploration

Try taking pictures of the night sky at different locations and analyze them, using the star counts as a measure of light pollution.

Visible light made by living creatures is known as bioluminescence. Fireflies are bioluminescent, and so are a few other land dwellers, such as some earthworms, centipedes, and fungi. On land, bioluminescence is rare, but in the oceans, it is very common. You can acquire digital images of bioluminescent organisms, such as fireflies or marine dwellers, and analyze the images to identify patterns of distribution.

Actually, you don't have to restrict yourself to bright objects—any objects that have a clear boundary and that can be thresholded are appropriate. Thresholding works best when the objects are distinct from or contrast with the background. You could look at lakes in Alaska from aerial photos or satellite images (has the total lake area increased or decreased?), cells on a slide, or structures in Landsat images.

With this technique, you don't have to be like William and Caroline Herschel peering through a hole in the roof. With ImageJ, you're only limited by the availability of digital images and your imagination.

Mission accomplished!

Shooting the night sky

The images for this lesson were captured using:
- a Canon Rebel XT digital camera with a 28-70 mm (non-digital) zoom lens,
- a tripod and cable release,
- ISO 400, and
- f/16 for 2 secs.

You can do astrophotography with a point-and-shoot digital camera, as long as it will allow you to make exposures longer than 15 secs.

What is light pollution?

Light pollution refers to the illumination of the night sky caused by artificial light sources on the ground (streetlights, billboards, etc.). Both the light and the loss of contrast make it difficult to find fainter stars and nebulae. – an increasing problem for both amateur and professional astronomers.