

BioEdSM

Scientific Image Processing

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by

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BioEdSM

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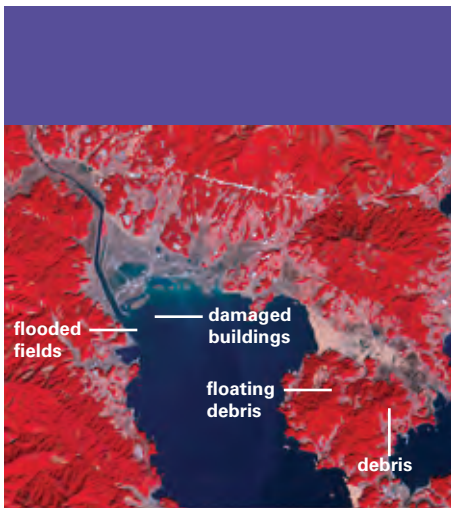
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HHMI

HOUSTON ENDOWMENT

A PHILANTHROPY ENDOWED BY JESSE H. AND MARY GIBBS JONES



Japan March 14, 2011



Japan March 1, 2007

On March 11, 2011, a large earthquake occurred off the northeast coast of Japan and triggered a tsunami that devastated coastal communities. Images from NASA's Terra satellite show dramatic changes before (lower image) and after the tsunami (upper image).

False-color imaging helps distinguish between water (blue); buildings and paved surfaces (blue-gray); farmland (brown to beige to pink); and vegetation (red).

The coastline shown has been totally reshaped. A long barrier beach is now almost completely gone. Flood waters sit on farmland. Debris, both floating and resting on land, extends eastward to Otomo, much of it lying over what had been farms. Photo courtesy of NASA Earth Observatory.

Digital Image Processing

Among the countless wonders of computer technology is user-friendly software that enables us to analyze and process digital images with great precision and detail. Many of us have used some form of image processing software to enhance vacation or family photos taken with digital cameras or smart phones. Other important applications for image processing include refinement and analysis of medical images (e.g., CAT scans and MRIs), satellite images of Earth, and deep space images from the Hubble Space Telescope.

In fact, NASA scientists have employed digital image processing for decades. When viewing digital satellite images of Earth, for example, scientists can use special computer software to highlight details that might be lost in natural color photos (see images, left). Water can be darkened to deep blue or even black to enhance its contrast with the land. Forest green is shifted to bright red, and agricultural plots may be shown in a pinkish hue. Urban areas often are shown in light gray or silver. Clouds and snow appear white and smoke appears hazy gray or blackish, depending upon its density. The capability to process images this way enables researchers to carry out a wide variety of analyses critical to life on our planet, such as determining the percentage distribution of crops or mineral deposits in a certain location, recording and monitoring changes in urban areas, mapping the extent of natural disasters, following the

spread of oil spills, and studying oceanic algae blooms in the ocean.

In concept, a digital imaging device (whether on a satellite or in pocket digital camera) dissects the scene being photographed into millions of points. Light reflected from the subject is focused on a chip, usually a charged coupled device, or CCD. The CCD is subdivided into pixels (picture elements) that act like tiny solar cells. Light falling on the pixels initiates a flow of electrons that are collected in the memory of the device (i.e., the "camera") as a long string of binary numbers (1s and 0s) representing light intensity. When the image is viewed on a display, such as the screen on a digital camera or a computer screen, the binary numbers are reconverted into tiny dots of light, arranged to create a detailed image of the original subject.

The photo processing software used in scientific research is similar to that available to consumers, but with more capabilities. One important capability of research software is measurement. If the length of an object in an image is known, a scale can be determined and used to measure unknown distances. Below, we describe a technique for measuring the length of or between items in an image.

ImageJ Software

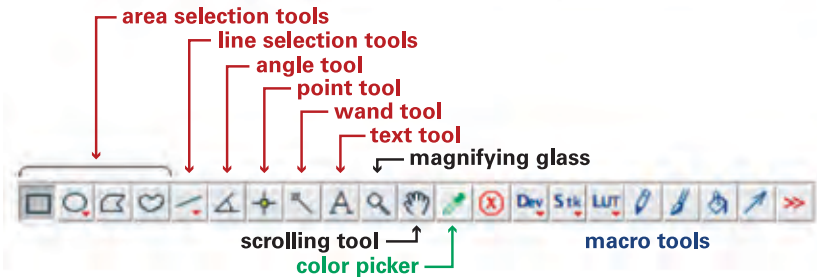
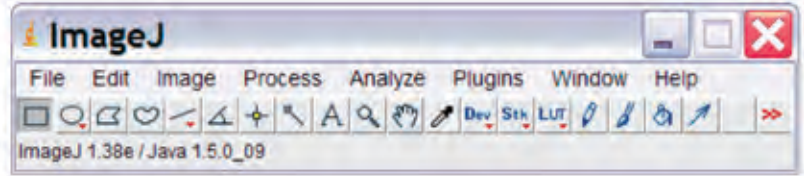
Use of image processing software is necessary to enhance and understand

Continued

ImageJ Website:

<http://rsb.info.nih.gov/ij/>

Menu Bar
Tool Bar
Status Bar



data from investigations aboard the International Space Station. ImageJ is an excellent, free public domain image processing software program which operates on different computer operating systems, including WIN and MAC platforms. Available from the National Institutes of Health, ImageJ can be downloaded, along with a detailed, downloadable user manual, from <http://rsb.info.nih.gov/ij/>.

ImageJ offers a wide range of tools and functions for analyzing digital images. After collecting images of your investigation subject(s) (one image is sufficient unless you are making a movie), you can use ImageJ to gather a variety of data, including the following.

- Measure the length of individual roots in plant-growing investigations.
- Determine the angles between primary and secondary roots.
- Measure the diameter of roots.
- Track the movements of organisms.
- Measure the angles of spider web strands.
- Graph the rate of root growth, based on daily measurements.

In addition, ImageJ will allow you to enhance image colors to bring out subtle details (be careful not to over-saturate colors). You also can stack sequential images, one on top of another, and play them back as a time-lapse movie.

Collecting Images of the Ground Investigation

To ensure that your images are useful for analysis, control variables and make sure the conditions remain as consistent as possible for all images. Each time an image is collected, the camera must be set up exactly the same way. Moving the camera closer or farther away, or tilting it differently from one shot to the next makes it difficult to compare images, and may require extra work to correct for scale/tilt before the images can be used. The tips below will help you to establish a controlled, uniform photographic method that produces consistent images that are easy to manage/organize.

1. Experiment with your digital camera prior to the investigation to determine the optimal distance and lighting for clear images.
2. Establish a known measurement for setting the scale with ImageJ. For example, place a small ruler next to the subject.
3. Develop a file name identification system that identifies the date and time each image is captured.

Measuring Length

The ImageJ program makes it simple to measure the length of objects within an image. Just follow these steps.

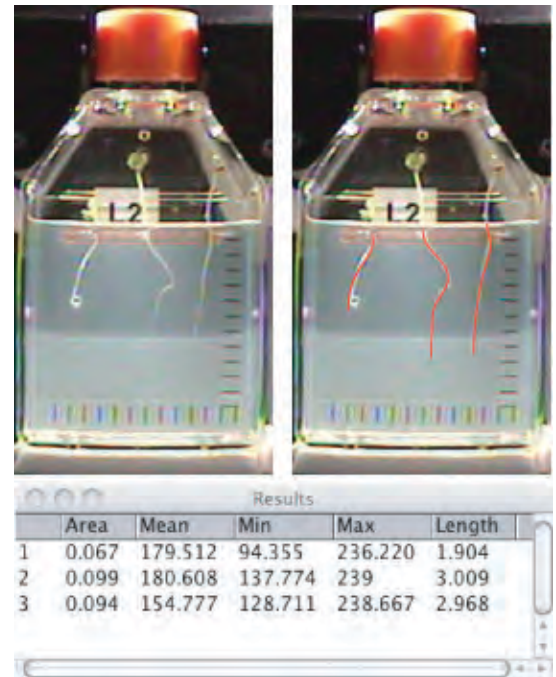
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The flask image on the far right has red lines drawn over the roots. Each red line has been measured by ImageJ. From left to right, the root lengths are 1.934, 3.009, and 2.968 centimeters.

Note: The tick along the right side of the flasks and along the bottom are 1/8 inch or 3.175 mm apart.



1. Select an item of known size within an image, such as a small ruler placed near the subject.
2. Using the line drawing tool in the ImageJ toolbar, draw a straight line across from one end of the known distance to the other.
3. Go to the “Analyze” option in the top menu bar and select “Set Scale.”
4. Type in the known distance of the line you drew in the “Known Distance” block. Do not enter units. If the known distance is 10 centimeters, for example, just enter “10.” Just remember that subsequent measurements you make for that image will be in centimeters.
5. Using the line tool, draw a line across a distance you wish to measure. Go to “Analyze” again and select “Measure.” A results window will display the distance in the units you are using.
6. The line drawing tool can be changed by holding down the control key and clicking on the tool (Macintosh) or right-clicking on the tool (PC). When you do this, other line tools will be displayed. The freehand tool is especially useful for measuring the length of roots that do not grow in a straight line.
7. To measure angles between primary and secondary roots, or between strands of spider web silk, select the angle tool. Click on a point and pull the line to the apex of the angle and click. Then pull the line to another point to complete the angle and click. Go to “Analyze,” and then “Measure.” The angle, in degrees, will appear in the results window.
8. Area can be measured with the closed-shape tools in the toolbar (rectangle, ellipse, polygon, freehand). Select a tool and draw the shape. Go to “Analyze” and “Measure.” The results table will display the area in square units (centimeters in our example).

Making Time-lapse Movies

1. Open all images you wish to combine into a movie in their proper sequence.
2. Click on “Image” in the top menu; open “Stacks” and then “Images to Stacks.” Click “OK” and the images will be combined into an animated movie.
3. To play the movie, go to “Image,” “Stacks,” “Tools,” and then “Start Animation.” The images will cycle repeatedly until you click “Stop Animation” to stop the movie.