ACS Technology Interim Progress Report

Project Title: Image Processing Exercises in Astronomy Using ImageJ

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During the spring (and summer) of 2005 I have been developing image processing exercises to be used in introductory astronomy classes. The exercises will be used this fall in our introductory astronomy class. After being tested in class, they will be revised and then made available on the web later this year. The exercises utilize the image processing program **ImageJ,** which is freely available from http://rsb.info.nih.gov/ij/. The code is written using the computer language Java and thus can be used on most computers. An advantage of the program is that it is open source and can be extended using the ImageJ macro language, or by using "plugins" written in Java. There is also a large world wide web of users who supply many useful extensions to the language. I thank Centre College student, Lyle Mantooth, for help in the programming. A brief summary of each exercise follows.

1. Introduction to Image Processing

This exercise teaches the fundamental ideas of image processing. Although most examples are from astronomy, it can also serve as a general introduction to image analysis. Students are shown that a digital image is just an array of numbers, where each number corresponds to the brightness of a picture element (PIXEL). The brightness is represented by a shade of gray in a gray-scale image, or by a particular color in a false color image. Since the image is just an array of numbers, mathematical transformations can be used to bring out different aspects of the image. These transformations may be divided into POINT, AREA, FRAME, and GEOMETRIC processes. In a POINT process, the value of a pixel is changed to a new value based only on the value of that one pixel. A commonly used point process is CONTRAST enhancement, where the pixel value (BRIGHTNESS) is changed using a mathematical function. An important statistical feature of an image is the HISTOGRAM. The histogram is a plot that displays the number of PIXELS having a given BRIGHTNESS. Students learn how the histogram can be used to decide what range of brightness should be displayed in order to improve the image contrast. In an AREA process, the value of a pixel is changed based on the values of the surrounding pixels. Examples of area processes are SHARPENING and SMOOTHING filters. A FRAME process combines different images together to improve the image quality. Examples of frame processes are the use of DARK and FLAT frames in the processing of CCD images. GEOMETRIC processes change pixel values based on transformations such as TRANSLATIONS and ROTATIONS. These transformations are used to align images, a process called image registration. In addition to applying these transformations, students learn how to measure lengths and areas of features in an image.

2. Measuring the Solar Rotation Rate

Students measure the solar rotation rate by finding the change in longitude of sunspots as a function of time. The measured planar image coordinates of the spots must be converted into the spherical solar coordinates of latitude and longitude. The problem is complicated due to the tilt of the rotation axes of Sun and Earth relative to the ecliptic. The relative orientation of these axes can be described by the angles, Bo and P, which must be known for accurate measurements of the solar rotation rate. The freeware program Heliov31 is used to calculate these quantities for a given date and time. We wrote an ImageJ plugin that solves for the sunspot latitude and longitude given Bo, P and the measured sunspot x, y coordinates. We also wrote an ImageJ macro that finds the sunspot's x, y coordinates. Students then use a spreadsheet to calculate the synodic and sidereal solar rotation rate. They compare their results with the expected value and also test for a dependence of the rotation rate on latitude (differential rotation).

3. Astrometry

Astrometry is the science of measuring the positions of objects on the celestial sphere. In this exercise students measure the positions of celestial objects in order to determine their proper motion and parallax. We wrote an ImageJ macro that finds the object's centroid x, y coordinates. We also wrote a plugin that takes these planar coordinates, along with those of 3 or more reference stars, and finds the object's Ra and Dec. Students then use astrometry to measure asteroid proper motion and parallax.

4. Moons, Craters and Mountains in the Solar System

Students compare the shapes and surface features of moons, asteroids and comets. They also measure the size of craters and estimate the height of a lunar mountain by measuring its shadow length. In a non-image processing activity, students calculate the kinetic energy of an asteroid and compare it to the energy released in nuclear explosions.

ASSESSMENT: How the Project Will Be Evaluated

Before the exercises are used in our astronomy lab, I am having them evaluated by Dr. Andre Wehner, who will be teaching the course this fall. I am developing an evaluation form to be used by the students so they can evaluate the exercises. When the exercises are placed on the web, I will request feedback from users.

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