# Imaging Processing Exercises in Astronomy Using ImageJ

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## BACKGROUND: Rationale for Overall Project

Image processing has become an important tool in many disciplines. Until recently, students had little familiarity with the subject. However, the availability of inexpensive digital cameras has revolutionized the field. Students have often performed basic image processing procedures, but probably have little idea what mathematical transformations are being applied to the image. The fundamental ideas of image processing are not difficult to understand and students can benefit by knowing what is happening to an image when they apply a processing tool. A problem faced in teaching image processing techniques is the lack of a powerful, but inexpensive, image processing program. Good image processing software is available, but it is often expensive and complicated to use. In addition, many programs are oriented toward photography and lack the tools useful in the sciences. ImageJ, a free program available from the NIH, solves many of these problems. Although designed for the biological sciences, it is quite powerful and can be used for most image processing tasks. It is also open source and can be adapted to specific problems. There is a large user base and many users share their extensions to the program. I intend to develop lab exercises that use ImageJ to introduce the fundamentals of image processing and then use these tools in an introductory astronomy class for non-majors. Most of the exercises will need just the standard ImageJ program. However, I also plan to learn the Java programming language so that I can extend the software to perform tasks that it is now not able to do. Most of the exercises will be used in the introductory astronomy class. However, I am in the process of developing an introductory physics class for biology students and plan to develop an image processing lab exercise for that class also.

## DESCRIPTION: Part of the Project To Be Done Under ACS Funding

I plan to develop the following lab exercises for my introductory astronomy class.

1. INTRODUCTION TO IMAGE PROCESSING
Students are shown that a digital image is just an ARRAY of NUMBERS, where each number corresponds to a PICTURE ELEMENT (PIXEL). This exercise will deal primarily with astronomical images where the numbers represent the BRIGHTNESS of the 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. In an AREA process, the value of a pixel is changed based on the values of the surrounding pixels. An example of an AREA process is a SHARPENING FILTER. A FRAME process combines different images together to improve the image quality. An example of a FRAME process is the use of a FLAT FIELD frame to remove defects in CCD images. A

GEOMETRIC process changes pixel values based on a geometric transformation such as a ROTATION. 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. The HISTOGRAM can be used to decide what range of BRIGHTNESS should be displayed in the image, and thus improve the image contrast. Images will also be analyzed to measure LENGTHS and AREAS of features in the image. The LENGTH measuring tool will often be used during later exercises. Other more specialized tools will also be introduced to show the power of image processing. These include analyzing an image to isolate objects and then having the computer count the number of objects. Students will then use ImageJ to process and analyze images using the processes introduced in the exercise.

2. CRATERS AND MOONS IN THE SOLAR SYSTEM
This exercise will have students examine images of moons, craters and mountains in the solar system. They will utilize the LENGTH measuring tool to measure the sizes of craters and the heights of mountains and craters on the moon. They will also use BRIGHTNESS/CONTRAST enhancement, FALSE COLOR, and SHARPENING filters to bring out subtle features in the images.

3. MEASURING THE SOLAR ROTATION RATE
A standard lab exercise in introductory astronomy courses is measurement of the solar rotation rate by observing the motion of sunspots. Students will use ImageJ to measure the pixel positions of sunspots and then use a spreadsheet to solve the equations that transform the 2-dimensional positions of the spots on the solar image to the angular positions on the solar surface. The solar rotation rate can be found by measuring the positions as a function of time.

4. PHOTOMETRY
Photometry is the measurement of the brightness of objects. Photometry is very useful in astronomy, particularly when the object is imaged through different filters. CCD photometry can now be done using relatively inexpensive astronomical CCD cameras. There is good astronomical software available to do photometry, but it is often too expensive to use in a multi-user lab. The software can also be more complicated than is desirable in an introductory class. I plan to extend the ImageJ software so that it can be used to perform photometry on CCD images.

5. ASTROMETRY
Astrometry is the science of measuring the astronomical coordinates of celestial objects. This is useful especially for newly discovered objects such as comets and asteroids. The image coordinates of reference stars having known absolute coordinates are first found. The image coordinates of the object to be measured are then measured. A mathematical transformation is then used to calculate the absolute coordinates of the object. ImageJ will have to be adapted to do this procedure.

I also plan to develop an introduction to image processing exercise for a physics course I am developing for biology students. It will be similar to the Introduction to Image Processing exercise described above, but will be oriented toward biology.

**TIMELINE: Deliverables/Milestones for ACS Funded Part of Project**

The proposed work will be performed from January - May (2005) during my sabbatical. The astronomy lab exercises will be used in the Fall (2005) astronomy class and the exercises will be available on the web at that time.

**TECHNOLOGY: Technical Requirements for the Project**

The only technology needed will be a computer and the ImageJ and JAVA software. I have a new computer in my office and the software is free. We have also recently purchased new computer controlled telescopes and CCD cameras that students can use to take their own astronomical images.

**OTHER SUPPORT: Institutional and/or Outside Support for Project**

I am on sabbatical this academic year. My primary research will be modeling astrophysical MASERS, but I will have sufficient time to develop the image processing exercises described in this application.

**LEARNING OUTCOMES: How the Project Will Enhance Teaching/Learning**

The exercises have two major learning goals for students. The first is to introduce students to the basic ideas and tools of image processing. The second is to use these tools to view and analyze images of astronomical objects. The work will also help my teaching by developing my skills in another computer language (JAVA) and teaching me the details of astrometry and photometry.

**CURRICULUM: How the Project Will Be Integrated into the Curriculum**

The astronomy lab exercises will be utilized in the fall of 2005 in the Introduction to Astronomy class at Centre College. The biological lab exercise(s) will be part of a new physics course for biology students that I am currently developing. This course is planned to be taught in academic year 2006/2007. In the meantime, I plan to make the exercise(s) available to my colleagues in biology.

**ASSESSMENT: How the Project Will Be Evaluated**

I will be developing an evaluation form to be used by the students in the Introduction to Astronomy class so they can provide feedback on the exercises. Before the exercises are used in the lab, I plan to have them evaluated by Dr. Andre Wehner, who will probably be teaching the course next fall. When the exercises are placed on the web, I will request feedback from users.

**Collaboration and Dissemination: How the Project Will Be Shared with ACS Colleagues**

I plan to make the lab exercises available on the web for ACS colleagues and any other people who are interested. I have no plans for collaboration at present. However, if the grant is approved, I will try to get a Centre student to help me develop the exercises on photometry and astrometry. This would probably be part of a directed study in astronomical observing.