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Imaging the Moon II: Webcam CCD Observations and Analysis (a Two-Week Lab for Non-Majors)

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Abstract. *Imaging the Moon* is a successful two-week lab involving real sky observations of the Moon in which students make telescopic observations and analyze their own images. Originally developed around the 35 mm film camera, a common household object adapted for astronomical work, the lab now uses webcams as film photography has evolved into an obscure specialty technology and increasing numbers of students have little familiarity with it. The printed circuit board with the CCD is harvested from a commercial webcam and affixed to a tube to mount on a telescope in place of an eyepiece. Image frames are compiled to form a lunar mosaic, and crater sizes are measured. Students also work through the logistical steps of telescope time assignment and scheduling. They learn to keep a schedule and work with uncertainties of weather in ways paralleling research observations. Because there is no need for a campus observatory, this lab can be replicated at a wide variety of institutions.

1. Introduction

Kwantlen Polytechnic University (KPU) offers an Astro 101 survey course for non-majors, with weekly labs. The activities presented here form a two-part lab in which students make real sky observations in week 1 and perform data analysis in week 2. Prior to this lab, students will have worked through a number of labs, including basic optics and image formation with lenses and mirrors.

The lunar imaging lab aims to demonstrate that observational astronomy involves quantitative data acquisition with instrumentation and to demystify the imaging process by making observations using familiar, everyday equipment where possible, rather than specialized apparatus. The lab also provides students opportunities to experience the joy and frustration of observing, and to make measurements from their own images. The value of prior planning and good note-taking in scientific work is reinforced because of the requirement to work through complex tasks separated in time across two sessions. The Moon has been selected as our real sky object because of its large angular size and brightness.

An earlier version of this lab using 35-mm film was presented at a previous *Cosmos in the Classroom* workshop (Sato 2004) and was in use until 2009. Photographic film became increasingly cumbersome to acquire and use, and we recognized that film photography had moved out of the typical student's experience. In the spirit of using familiar, everyday equipment, the decision to use the webcam-based imager my department experimented with in the 1990s ('KPU Mk I') was revisited. At that time, the webcam was a new consumer technology and the user experience was not found to be sufficiently smooth, prompting us to defer classroom implementation until recently.

2. Equipment

The *Imaging the Moon* lab is designed to be implementated without a campus observatory. The main components are (1) a small telescope, (2) a USB-operated camera adapted from a webcam, and (3) a computer (Fig. 1). All are widely available consumer products. At KPU, we use 8-inch telescopes, which are larger than needed for lunar observations.

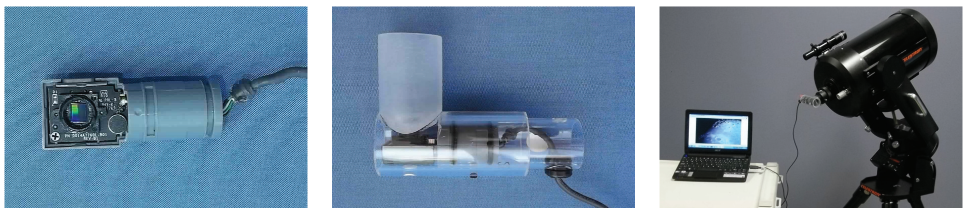

Figure 1. Camera and telescope. Left: The lens and much of the casing is removed from an ordinary webcam. Center: KPU Mk II camera. The new packaging fits the eyepiece holder of telescopes. Right: An 8-inch telescope equipped with a KPU Mk II camera controlled by a netbook computer.

The adaptation and use of webcams is now well established in the amateur astronomy community (e.g., Buchanan 1998; Schröder and Lüthen 2009). In this application, the lens and much of the factory casing of a webcam are removed and discarded (Fig. 1, left). The remainder of the electronics is retained. A tube matching the diameter of an eyepiece is placed over the imaging chip such that the CCD can be placed directly at the focal plane of the telescope (Fig. 1, center). Although it is now possible to purchase an equivalent finished product from amateur astronomy retailers (e.g., Orion Starshoot USB Eyepiece Camera II), we produced our own cameras (KPU Mk II) to reinforce the idea that they are made from common webcams.

3. Lab Activity

At KPU, the lunar observation lab runs over two sessions: one for observations and one for data analysis. After identifying ranges of dates with an evening Moon, groups of four students sign up for 50-minute observing shifts at our 8-inch telescopes. The class then waits for the first clear night. Student lab manuals and related materials are available online.[1]

3.1. Week 1: Observations

The first 30 minutes of the observing session are applied to orientation. Students make naked eye and eyepiece observations to become familiar with the object to be imaged, plan their grid patterns for mosaic construction, and prepare observing logs in their lab

[1] See http://www.kpu.ca/science/physics/faculty/takashi_sato/COSMOS2013.html

notebooks. Each group is given a camera and a netbook computer. They can also watch an earlier group taking data.

For the final 20 minutes, the group takes charge of a telescope and mounts the camera. A series of images is captured using stock webcam software. As we do in research observations, students are prompted to ensure they obtain enough data for meaningful analysis within the alloted telescope time. Experience shows that 20 minutes is ample time for groups to complete their observations and for the class to stay on schedule.

3.2. Week 2: Analysis

During the second week, students produce a mosaic of the Moon's face (Fig. 2) using digital tools. Microsoft PowerPoint works well for this purpose and is familiar to students.

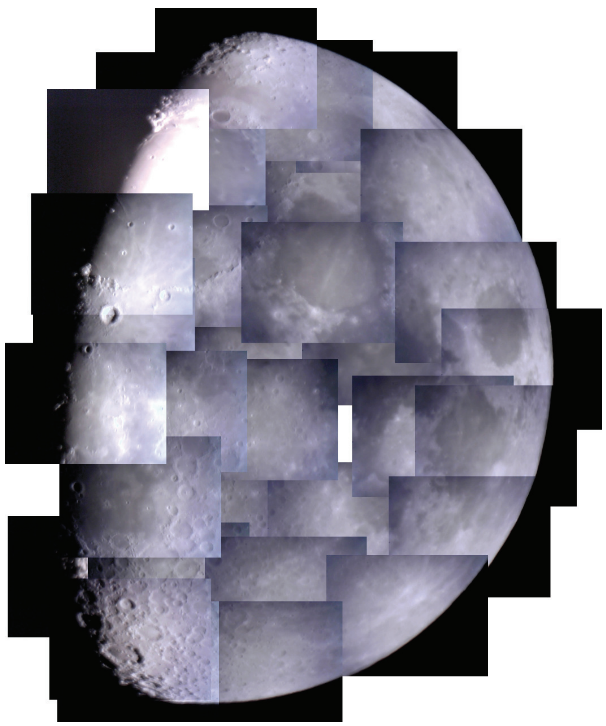

Figure 2. Typical student result. A mosaic is produced from a series of image frames. The gap in coverage near the image center is a common and familiar feature. The overexposed frame in the upper left is discussed in Section 4.2.

Crater size measurement is a quantitative analysis activity at a level appropriate for Astro 101. Craters are identified on students' own images using lunar maps and globes. Students then establish the image scale, measure crater sizes on the image, and convert them to projected distances on the lunar surface. Students conclude by comparing each measured crater to a familiar geographical feature on Earth (e.g., "crater Copernicus is about the size of Lake Erie").

4. Discussion

4.1. Lab Development

Simply replacing the original 35-mm camera with an unmodified webcam results in an image scale that makes it simple to acquire a very pleasing image of the Moon with only a single exposure, but make the lab too simple. By removing the lens from the webcam, the new image scale places each frame across a small region of the Moon. In order to build a mosaic, students must plan their observations and take good notes (observing log). These steps align well with the learning objectives of the course.

4.2. Technical Issues

The webcam software used by the students is furnished with the computer or the camera. By default, typical software appears to set the exposure level based on average pixel value across the frame. This normally yields good results if the Moon fills the frame, but if blank sky is a significant part of a frame, this algorithm is not optimal and the result is an overexposed lunar surface on gray background (see, for example, Fig. 2 upper left). This was a known issue from the 1990s work with the KPU Mk I camera. Although today's webcam software typically provides a manual override option, this refinement is beyond the scope of our non-majors course, and we simply retain the default settings.

An interesting and unexpected issue is that the CCD chips inside nominally identical cameras can vary in size, resulting in varying sky coverage.

4.3. Student Work

The resulting images (e.g., Fig. 2) display reasonably high quality, generally limited by seeing. Although software exists to assist in mosaic building and smoothing the frame edges, we consider this to be beyond the scope of the lab. The mosaic building process has proven to be a good illustration of the merits of good note taking in science. While most students plan reasonable grid patterns and keep observing logs as instructed, many of those who ignore these steps have found themselves unable to construct the mosaic.

There have also been many examples of student excellence. Some students discover that by switching the telescope tracking off, they can naturally let the Moon drift across the CCD while they capture images. Unlike with the 35 mm cameras, most students arrive confident about camera operation, so much so that we have not had to provide detailed instructions on how to operate the cameras.

5. Summary

Imaging the Moon has been a successful lab implemented with only modest equipment. The observing sessions are fast-paced and fulfilling for students and instructor alike. Students consistently report enjoying observing and learning that measurements can be made from their own images. The lab has evolved to employ today's common camera technology ("no specialized apparatus"). In anticipation of a future without webcams, I have begun exploring the use of smartphones, and I look forward to making a report in the near future.

Acknowledgments. I wish to thank Mr. Bob Chin for the design and construction of the KPU Mk II cameras based on my prototype constructed using electrical tape.

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