Observing the lunar crescent through electronic cameras

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Abstract

Astronomical observation possibilities have greatly improved in the last decades with the availability of electronic cameras and inexpensive computers. These tools can be used to reliably image and show objects with very low contrast, beyond the capabilities of the human eye. Thin lunar crescents often have low contrast to the background sky and thus are difficult to see visually. Viewing with real-time contrast enhancement has proven to be a powerful tool to observe such lunar crescents: this method of astronomical observation has crushed some supposed limits of crescent visibility, as demonstrated by showing the lunar crescent at the moment of conjunction, far below the “limit” of Danjon. We explain the technical details of this observation method and discuss its properties and applications.

Introduction

Electronic imaging of the moon and planets is not new or unusual. The tools and methods of digital imaging are widely used by amateur astronomers on all manners of astronomical objects. In recent years a specialized approach has been developed by several groups, which uses these existing methods to image low-contrast lunar crescents and also show them in real-time on the computer screen. This approach allows to detect very slender crescents and can also make a crescent visible despite somewhat unfavourable weather conditions such as dust, haze and even thin clouds.

System overview

The telescope optics creates an image of the crescent. This image is captured by an electronic camera. Specialized software is used to operate the camera. The images from the camera are processed in real-time to improve the visibility of the crescent and displayed on the computer screen. Special baffles on the telescope can be used to allow the safe observation and tracking of the crescent during daytime, even when it is close to the sun.
The telescope mount points the telescope optics at the calculated position of the crescent and tracks the calculated movement of the moon across the sky, keeping the crescent in the field of view of telescope and camera.

Technical details

Optics

The telescope optics must be of good quality, to capture the low-contrast image of the crescent. The optics should be chosen in such a way, that the focal length of the optics allows the full width of the moon to be imaged on the sensor of the electronic camera. With very narrow crescents the limited resolution of the optics at longer wavelengths might come into play, so the optics should not be to small in diameter. The optics should have good colour correction, as the crescent is often imaged through red or near infra-red colour filters to improve contrast between crescent and sky. In our recent experiments, a high-quality refractor with a diameter of 110mm and a focal length of 770mm has worked well.

Camera

The electronic camera should be a fast industrial video-camera, with a sufficiently large sensor (e.g.

2/3" sensor size), high resolution (e.g. 1280x960 sensor elements), high sensitivity and low noise. Monochrome sensors are generally far more sensitive and versatile than colour sensors for this application. The camera should also provide a fast frame-rate of 15fps or higher, to provide a good real-time display. The specific camera needs to be supported by specialized software which does the real-time image processing and contrast enhancement. Camera and software are critical parts of the overall system, as the software output is what the observer actually sees.

Telescope mount

The optics and camera need to be mounted on a sufficiently sturdy astronomical telescope mount, with good “GoTo” capability and precise tracking of the crescent across the sky. If specially designed baffles for daytime observation near the sun are required, the mount has to carry a considerable load. Many different types of telescope mount are readily available from various manufacturers which meet these requirements.

Baffles

Special care must be taken, if the crescent is to be observed or tracked during the day: The proximity of the glare of the sun to the field of view poses a serious danger of damage to the instruments and even bodily harm to a careless observer. Special tools and care must be used to deal with this problem: A dedicated baffle system should be used to prevent the bright light of the sun from entering the telescope. Special care must be taken when aligning and slewing the telescope. The baffle system can be quite long if observing very close to the sun is intended, which adds a substantial load and torque for the telescope mount to handle. This load needs to be considered when selecting the mount and mechanical components.

Imaging software for real-time contrast enhancement and viewing

The electronic camera is operated through specialized software on a current standard personal computer. The specialized software controls the camera settings and processes the stream of images from the camera, to improve visibility of low contrast detail. During the day, the computer screen or projected computer image probably needs to be shielded from direct light. The effects of the proper use of the specialized software are quite dramatic: Faint detail on the lunar surface can be made visible on the screen, when the human eye can hardly detect the low-contrast lunar disk in the sky.

Image processing details

- The main feature of the specialized software is real-time contrast-stretching of the image data: e.g. stretching the digitized brightness range [210; 230] of the captured image to [0; 255] for display. This step alone greatly improves the visibility of low-contrast detail, which differs little from the brightness of the background.
- Additionally, the use of calibration data to deal with the effects of vignetting and variations of pixel sensitivity (known as "flat-fielding") removes these distracting effects from the images and allows crescent detail to become more visible.
- Furthermore, several images captured in rapid sequence can be mathematically combined (known as "image stacking") to reduce random noise components in the resulting image and allow even fainter detail to become visible.
- All these steps are done in real-time, so that a live-image of the contrast enhanced crescent is displayed.

Operating procedure

The following steps would be performed in a typical observation attempt of a faint lunar crescent in the evening sky. Preparation would begin during the day and the crescent would be tracked till after sunset:

1. Set up and align the telescope mount. This only needs to be done once for a stationary telescope.
2. Align the telescope with the current date and time, using some easily visible celestial object. The sun can be used for this task during the day, but a special solar filter must be used to deal with the dangerous glare. The solar filter must be removed afterwards.
3. Focus the telescope precisely at infinity by imaging some celestial object. Planets and bright stars can be used for this task, which a well aligned telescope mount can easily slew to. The camera should have been attached in some well defined angular position, so that the crescent orientation is known in advance.
4. Slew the telescope to the position of the crescent.
5. Adjust the configuration of the baffle, so that the light of the sun is completely blocked from the telescope optics.
6. Adjust the settings of the camera (exposure, gain, frame-rate, resolution, binning) and processing software (contrast-stretching, frame-stacking, flat-field), so that the crescent becomes visible.
7. Capture and save images and videos, to document your observation. Additional pictures of the instruments and sky conditions are also of interest.
8. Monitor and adjust the exact tracking speed of the telescope mount and the settings of the camera software while the crescent moves across the sky.
9. Share and enjoy the view.

Advantages and benefits

- The central reason for using this observation technique is the drastic improvement in the visibility of low contrast crescents. With a dedicated effort the crescent could actually be imaged almost every day of the year from a location with excellent weather conditions.
- The imaging approach also improves the credibility of the observation results: Simple "seen / not seen" reports are extended and strengthened by the captured images and meta-data.
- Images and meta-data provide excellent documentation of observations. This could even be used for the improvement and extension of existing visibility models, as the central aspect of contrast is captured in the images.
- This observation method does not require good eyesight or personal experience with telescopic viewing for success. Each member of a very diverse group of observers would have the same chance to see the crescent during a joint observation.
- The technique scales to any number of observers from a single telescope. Even public viewing events with image projection systems and huge crowds could easily be done. Direct broadcast and transmission of the images would easily be possible.
- The approach also demonstrates the precision and correctness of astronomical calculations to the layman, as these calculations are the basis of pointing the telescope at the correct position in the sky. The precision can be demonstrated by experiment, again and again. No reasonable doubt should remain.

Disadvantages

- Electronic imaging of the lunar crescent simply might not be the kind of observation somebody wants to do.
- Imaging is more expensive than pure visual observation with the same telescope. This aspect is mitigated and even reverted by making the images available to many people.
- The technical tools involved require some skill and experience to use, but most of these skills are readily available with astronomy enthusiasts.

- The image of an electronic camera is aesthetically less pleasing than visual observation of a slender crescent, but this is only relevant when visual observation succeeds without great efforts. For such situations, the contrast-enhancement would not be required anyway.
- Electronic imaging of the crescent might be somewhat difficult to explain to the layman, but that should only be a matter of a well prepared demonstration on an easy crescent.

Applications

1. The imaging approach allows the direct observation of the lunar crescent on most days of the year, even if the sun is in the sky. Several other objects such as planets and stars can also be shown under similar circumstances. Such observations demonstrate the correctness and precision of the involved astronomical tools and methods.
2. The imaging approach is also a useful aid for visual observations, by showing the exact location and orientation of the crescent, thus "guiding" the human eye of visual observers. Visual observations of difficult crescents can be attempted with a greater chance of success, by using two telescope optics, one each for imaging and visual observation, mounted side by side on the same telescope mount. If both optics are well aligned with each other, the visual observer knows where to look when the imaging system shows the crescent in the middle of the common field of view.

Results

- The camera based approach has demonstrated, that conjunction is not a magical moment: An illuminated edge of the lunar disk (a "crescent") exists before, during and after the theoretical moment of conjunction (unless there is a total solar eclipse in progress), even if it is of very low contrast and difficult to detect.
- The Danjon "limit" of 7° elongation has been shown to be no hard limit at all, but rather a rule of thumb for when visual observation gets really difficult. The lunar crescent has been imagined at the moment of conjunction (in daytime) at less than 5° elongation from the sun. Practical limits for dedicated visual observation and imaging observation still need to be determined.
- The imaging technique has proven to be reliable for the regular observation of low-contrast structures such as the lunar crescent in daytime or twilight. Dozens of observations of all kinds of celestial objects have been done.
- The combined approach of visual observation and imaging simplifies the task of the visual observer, by using a parallel imaging scope to pinpoint the exact location of the crescent. This approach has been used to good effect in recent observations, when the lunar crescent could easily be imaged after sunset at 6.5° elongation, which simplified the visual search for the elusive crescent.

Summary

Imaging with electronic cameras has proven to be a powerful tool for the observation of low-contrast crescents, which are often caused by unfavourable geometry or sub-optimal weather. The chance to show the crescent moon to many people at once, day after day, can help in promoting a science based approach to moon-sighting and can also assist with traditional visual observations.
One could easily place such a system at a good observing site and provide a "Live crescent watch" TV program on almost every day of the year. Such visual evidence would be a powerful educational tool and would probably work well against certain kinds of erroneous sighting claims.