A Dark Box for Camera Measurements

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Introduction

This paper describes a *dark box* for measurements of camera performance under low-light conditions. The dark box was constructed to test and verify the operation of the *cama* and *luma* suite of programs, but it would also be useful for investigations of the camera low-light noise performance. The dark box has a controllable light source so that the internal luminance can be varied between 16 and 26 magnitudes per square arcsecond (MPSAS). A reading of 16 MPSAS corresponds to a very light-polluted urban sky; a reading of 26 MPSAS is darker than any sky found in nature.

The dark box is convenient to use in practice since it can sit on a lab bench and be operated in daylight from a nearby computer while still achieving a maximum darkness rating of 26 MPSAS. This is much more convenient than using a darkroom or camera change bag.

Figure 1: Camera, Light Source and SQM

The *cama* program controls the operation of a DSLR from a computer. The *luma* program analyses a DSLR image for brightness in luminance in candela per square metre and sky quality measurement in magnitude per square arcsecond.

Description

The dark box contains the DSLR camera under test, a Unihedron SQM-LU meter [1] for monitoring light level, and a controlled LED light source, all mounted as shown in figure 1.

The camera and SQM are connected via a USB cable to a computer which is running programs to read the light level [2], control the camera and determine the luminance of the image [3].

The LED light source is a white LED which shines through a ping-pong ball diffuser. Connections to the LED are brought outside the box to a control circuit.

Control Circuit

The LED control circuit is shown in figure 2. The circuit is basically a constant current source for the LED. The ten-turn potentiometer R3 establishes a voltage Vs at the non-inverting terminal of the op-amp. The op-amp then adjusts it's output so that the same voltage appears at the inverting terminal. This voltage appears across R4, which is in series with the LED. Consequently, the current through R4 – and the LED – is equal to Vs/3300 amperes.

With the switch S1 closed, the maximum value of Vs is about 10 volts. This is then the 'high intensity' range, which results in light values of approximately 16 to 21 MPSAS. With switch S1 open, the maximum value of Vs is about 70mV.

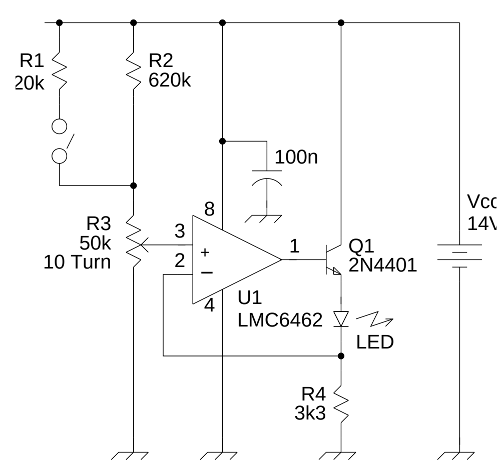


Figure 2: LED Current Controller

This is then the 'low intensity' range, which results in light values of 19 to 26 MPSAS.

The SQM responds very slowly at low light levels, which makes it somewhat inconvenient to set a specific light level. It is therefore convenient to monitor the voltage Vs with a digital voltmeter, since Vs is a good indicator of the LED brightness and one quickly learns to relate voltage to SQM reading.

Most components of the control circuit are not critical. The light emitting diode was a no-name high-intensity white LED. It is however important that the operational amplifier have very low input bias current to avoid affecting the current through the LED. The LMC6462, with 0.15pA input bias current and 0.25mV offset voltage, is recommended.

The Box

Figure 3: The Dark Box

The box is a re-purposed container for reams of printer paper, `11 x 18 x 8` inches (`28 x 46 x 20` cm), obtained for free from the local Staples business stationery store. Corner holes and handle openings are covered with Gorilla tape. The instruments sit in what was the original lid of the box (figure 1) and the original base becomes the lid of the dark box. The two USB cables (for the camera and SQM) snake through the end of the base unit and openings are closed with Gorilla tape.

The top of the box has a 6 inch (15 cm) wide strip of plasticised, opaque fabric that overlaps the base when the top and base are assembled.

Both the inside and outside of the box are spray painted matte black. The surface on the lid opposite the camera is covered with matte-white foam-core material. A central target helps align the camera and provide a visual image for checking photographic contrast.

Software

The SQM-LU meter is controlled by a custom program in the Tcl programming language. Figure 4 shows the graphical user interface. The camera is controlled by `CAMA` (Camera Automation), another Tcl program, figure 5(a). Image analysis is by a third Tcl program, `LUMA` (Luminance Analysis), figure 5(b). The CAMA and LUMA programs are described in detail in [3].

For further information or to obtain copies of these programs, please contact the author at the email address `phiscock@ee.ryerson.ca`.

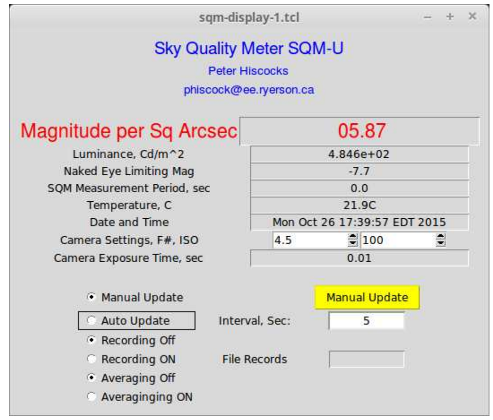


Figure 4: SQM Control Software

Workflow

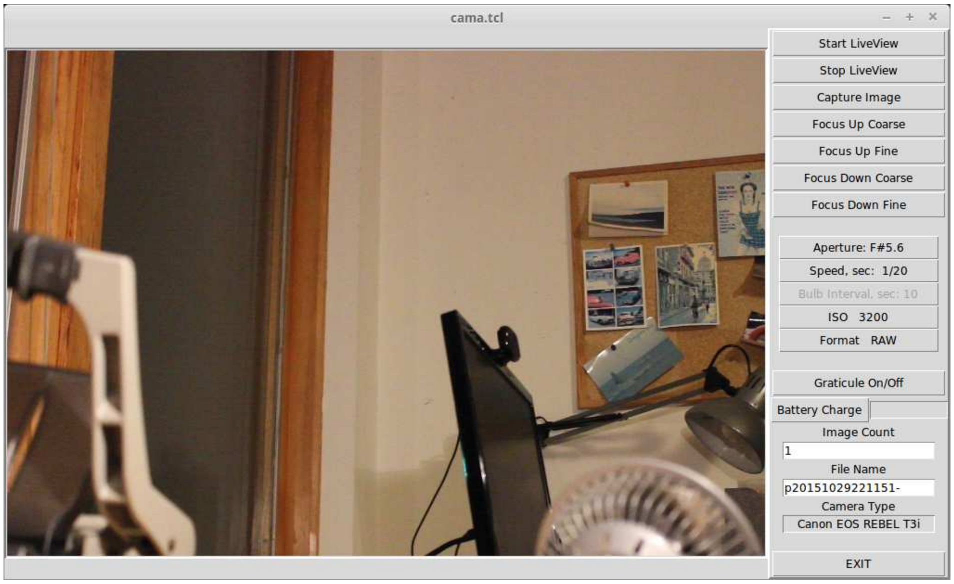
First, the camera must be calibrated. This need only be done once[1].

- With the camera image format set to RAW, photograph a known source of luminance such as the aperture of the integrating sphere described in [4].
- Load that image into LUMA. Select the appropriate area of the image, such as the aperture of the sphere.
- Adjust the Camera Calibration value on the LUMA user interface until the readout value of luminance is equal to the calibration value. Note that calibration constant, which applies to this particular camera.

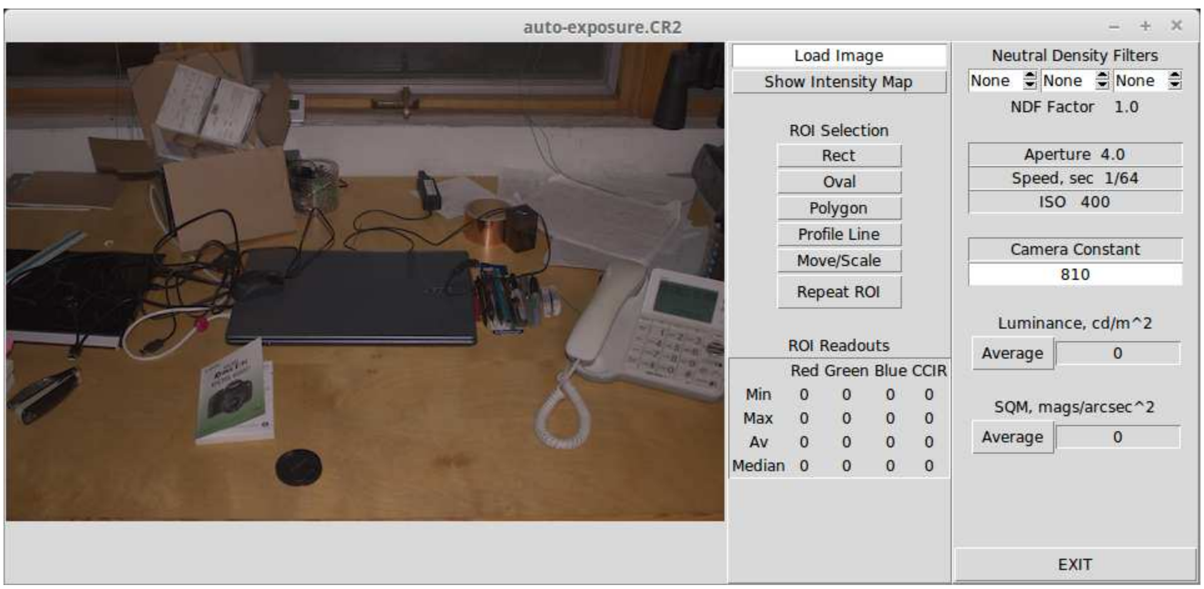
Now it is possible to use the same camera for a low-light photograph in the dark box.

- Mount and connect the DSLR to the host computer, using its USB cable. Turn the camera ON and set the mode to MANUAL. Take off the lens cap.
- Mount and connect the Sky Quality Meter to the host computer, using its USB cable.
- Power up and check the light source.
- Close up the box.
- Set the light level to some desired value by adjusting potentiometer R3 in the control circuit while observing using the SQM value on its readout.
- Using CAMA or some other camera control program, set the camera parameters: sensor ASA, aperture, shutter speed. Take an image.
- If LUMA is present and running on the same computer, CAMA will send that image to LUMA. Otherwise, save the image to the computer and manually load it into LUMA.
- Select the area of interest (usually the centre of the frame, deliniated by the circle). LUMA will calculate the luminance in that area. The value should agree with the value obtained on the SQM interface.
- Now you can additional low light level tests on the image, such as measuring the background noise value.

[1] Currently this work flow has been tested only for Canon RAW and TIFF images.



(a) CAMA: Camera Automation



(b) LUMA: Luminance Analysis

Figure 5:

References

[1] *Sky Quality Meter - LU*
Unihedron
http://unihedron.com/projects/sqm-lu/

[2] *A Sky Quality Meter Display*
Peter D. Hiscocks
http://www.ee.ryerson.ca/~phiscock/papers/sqm-display-paper.pdf

[3] *Calibrated Measurements of Luminance and Sky Glow with a Digital Camera*
Peter D. Hiscocks
International Conference on Light Pollution Theory, Modelling and Measurement
Mai 2015, Jouvence, Quebec, Canada.

[4] *Integrating Sphere for Luminance Calibration*
Peter D. Hiscocks
http://www.ee.ryerson.ca/~phiscock/