Data Descriptor

Data and code for analyzing performance of QHY CMOS cameras

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Abstract: Expensive cameras meant for research applications are usually characterized by the manufacturers and detailed specifications [1] are available for them. Suppliers of inexpensive cameras usually do not provide such detailed information about their cameras. This data set provides the acquisition speed and noise characteristics acquired from a monochrome 1.2 megapixel CMOS camera, the QHY5L-II M [2]. The source code provided along with this data set [3]can also be used to acquire similar data for other QHY cameras. This enables the use of such cost-effective cameras for other scientific applications in other fields, beyond the designed use in Astronomy.

Keywords: Imaging; CMOS; camera; SNR; noise; performance.

Data Set License: CC0

1. Introduction

A wide variety of inexpensive imaging devices are currently available. Prices have been driven down by the economies of scale brought about by the proliferation of mass-market devices like smartphones. But imaging devices for scientific purposes remain expensive. In many cases, the key differentiator between mass-market devices and the devices meant for scientific applications are the detailed data-sheets of the latter [1]. The code and data presented here can be used to evaluate an entire range of cameras from a low-cost manufacturer, and use appropriate models for applications beyond Astronomy, for example in biomedical imaging.

2. Results

Our data was used to circumvent the lack of documentation about the camera and in the software development kit (SDK) [4]. We could evaluate the QHY5L-II M camera's performance characteristics. This helps us to design parameters like exposure control, binning and averaging for using this camera in biomedical imaging. Our code can be used to similarly evaluate other camera models from the same manufacturer.

3. Discussion

Data and code is presented for the following measurements:
1. Mean and standard deviation of a single pixel of the camera under dark conditions, averaging over 10 or 100 frames, and with frame-to-frame subtraction.
2. Mean and standard deviation of a single pixel of the camera under illuminated conditions, averaging over 10 or 100 frames, and with frame-to-frame subtraction.
3. Mean and standard deviation of all pixels of the camera under dark conditions, with and without averaging and frame-to-frame subtraction.

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4. Mean and standard deviation of all pixels of the camera under illuminated conditions, with and without averaging and frame-to-frame subtraction.
5. Mean and standard deviation of all pixels of the camera under dark conditions, binning 2x2 pixels, with and without averaging over 10 frames, and with frame-to-frame subtraction.
6. Mean and standard deviation of all pixels of the camera under illuminated conditions, binning 2x2 pixels, with and without averaging over 10 frames, and with frame-to-frame subtraction.
Data and code are also presented for miscellaneous other useful demonstration applications which can be used for checking brightness of illumination, measuring the number of frames per second (fps) delivered by the camera for various resolutions, checking for periodic noise in the images delivered by the camera using 2D Fourier transforms, and so on. Documentation is also presented along with the raw data as Supplementary Material, indicating which section of code produced which data.

Our data was used to circumvent the lack of documentation in the software development kit (SDK). For example, the CONTROL_GAIN parameter accepts integer values, but our data (data file 058) shows that only values 0-99 are actually used by the SDK to change camera gain. This is illustrated in Figure 1.

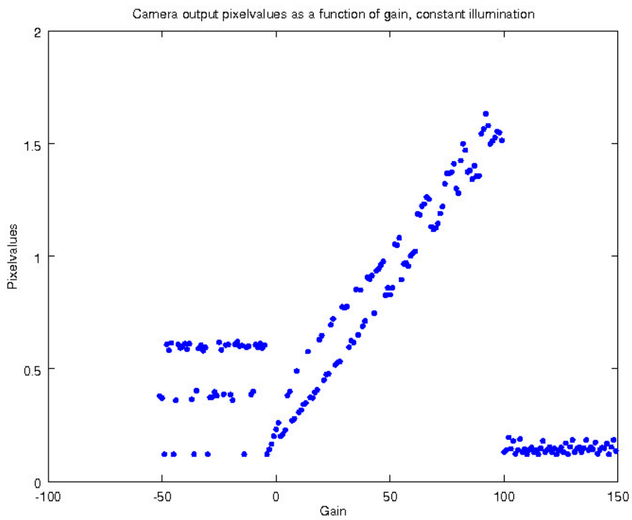

Figure 1. Camera output pixelvalues as a function of control gain SDK parameter under constant illumination. We see that negative values and values over 99 do not result in linear gain control.

Similarly, we learnt from the frames per second data (data file 002) that the exposure time parameter is in microseconds. We also find the performance limits of this camera - a maximum of 200 fps for smaller resolutions, and a maximum of 29 fps for full resolution captures. This is brought out in Table 1.

Table 1. Frames per second (FPS) captured by the QHY5L-II M camera. Complete raw data is available in data file 002.

Resolution	CONTROL_EXPOSURE	FPS	Comments
32x24	1	200	This is the fastest FPS.
320x240	1	200	
320x240	10000	99	Indicates CONTROL_EXPOSURE is in μ sec.
1280x960	1	29	This is the limit for full res.

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Varying exposure time under constant illumination (data file 022) showed us that the SDK varies exposure only in multiples of around 100 microseconds. This is illustrated in Figure 2, where we see the pixel standard deviation clearly following a step function.

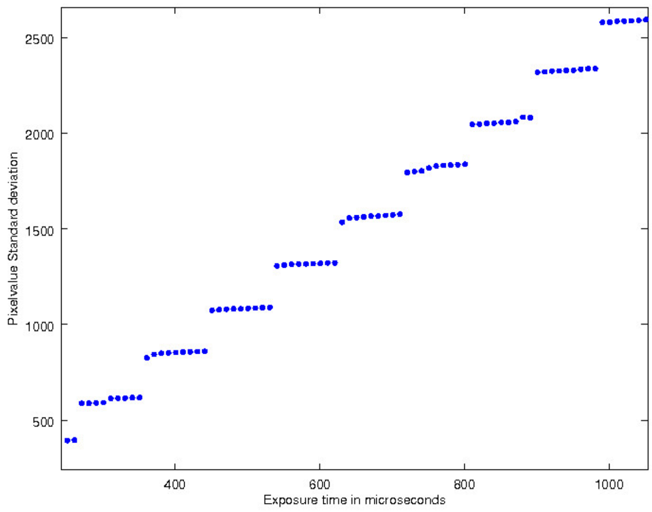

Figure 2. Camera output pixel value standard deviation as a function of CONTROL_EXPOSURE SDK parameter under constant illumination. The step function response indicates that the actual exposure time varies only in steps of around 100 microseconds.

From our data, we could compare the worst case signal to noise ratio (SNR) of unaveraged, averaged and averaged binned frames captured using this camera with gamma and gain set to unity, to the expected SNR of the internal 12-bit analog to digital converter (ADC). The apparent reduction in standard deviations of pixel values for high intensity readings in our data (data file 022) are due to saturation of some parts of the image. The full well capacity (FWC) of the sensor used in this camera is not mentioned in the official specification sheet [4]. Since the noise in images captured varies as (FWC) as for an ideal detector [5], we looked for the scale factor which would make our noise data follow such a square-root curve. We found that a curve corresponding to a FWC of 23000 is a close approximation. This is shown in Figure 3. Averaging images over n frames (data file 022) improves SNR by a factor of (n) as expected. We obtained similar performance figures by testing a second camera of the same model (data files 036 - 047).

 doi:10.20944/preprints201810.0179.v1

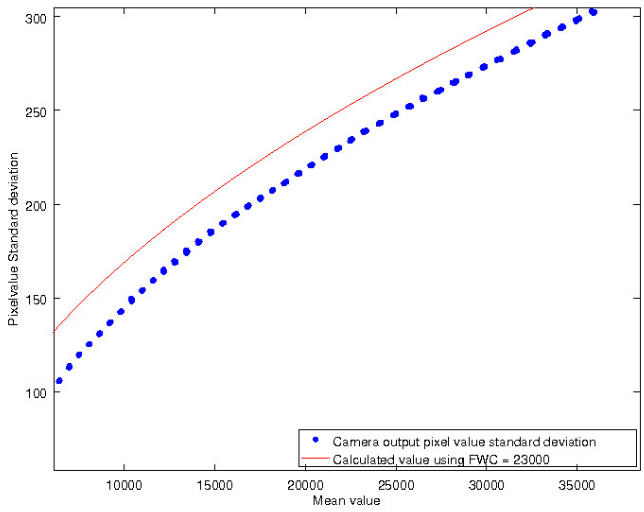

Figure 3. Camera output pixel value standard deviation as a function of mean pixel value under constant illumination. The calculated curve indicates that the equivalent full well capacity (FWC) is close to 23000.

4. Materials and Methods

Image capture and analysis code was written in C++ using the QHY Linux software development kit (SDK) [4] and the OpenCV library [6]. Natural light was used for the illuminated tests, using the camera without any lens, pointed at a paper diffuser, and dark tests were done by covering the camera with its black nose cap. Our code can be used to test cameras using the EMVA 1288 specification [7] also.

Supplementary Materials: The raw data acquired during this study is available online, and the code is available at https://github.com/hn-88/QHYCameratests.

Acknowledgments: The authors express their gratitude to Bhagawan Sri Sathya Sai Baba, the founder Chancellor of their institution, for help and guidance throughout this work. The authors' department has infrastructure funding from Department of Science and Technology, Government of India (DST) (FIST 2012-2017 SR/FST/PSI-172/2012).

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

SDK: Software Development Kit
CMOS: Complementary Metal-oxide Semiconductor
EMVA: European Machine Vision Association

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