Digital Canopy Photography: Exposed and in the RAW

Craig Macfarlane, Youngryel Ryu, Gary Ogden and Oliver Sonnentag

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Overview

- ~~Why canopy photography~~?
- Where does photographic exposure fit into the key steps and
- Why is it a problem?
- Fixing the problem by shooting RAW.

Key steps


Image capture
exposure

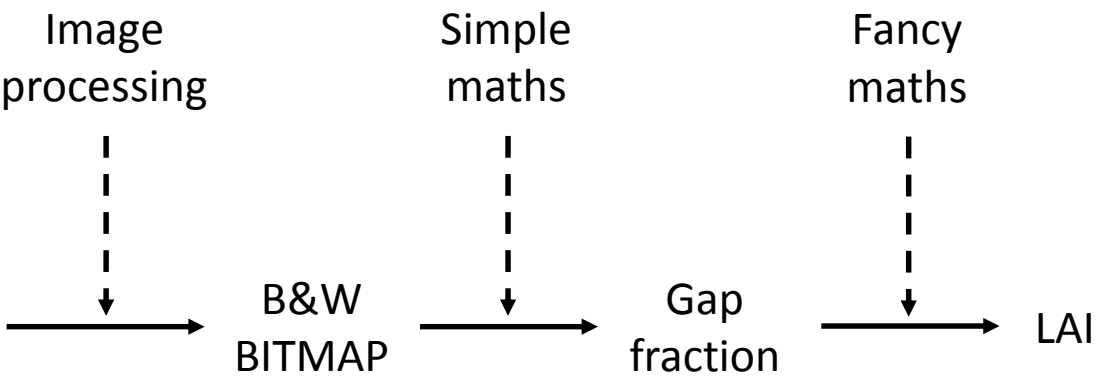
Image processing
Simple maths
Fancy maths
B&W BITMAP
Gap fraction
LAI

What is exposure?

- The amount of light reaching the film/sensor.
- Determined by ISO, lens aperture and shutter speed.
- A ‘one stop’ change in exposure represents a halving or doubling of the amount of light hitting the film or CMOS/CCD sensor.

What's the problem?

- Photographic results are sensitive to exposure.
- Automatic exposure results in underestimation of LAI in dense canopies and overestimation in sparse canopies.
- About 10% change in LAI for a 1 stop change in exposure.

Baekshafer et al. 2013

Auto-exposure = 13

Made some effort = 28

Didn't say (auto-exposure?) = 20

Exposure determination method	Number of publications	Found in
Auto-exposure	13	Bao et al. 2008, Clark et al. 2003, Davi et al. 2009, Englund et al. 2000, Guevara-Escobar et al. 2005, Hanssen & Solberg 2007, Inoue et al. 2002, 2004a, 2004b, Inoue et al. 2011, Jonckheere et al. 2005, Promis et al. 2011, Thomas 2011
Bracketing (auto-exposure, -1, -2 EVs or auto-exposure, +2, -2EVs) and selection of "best" photograph	5	Baudet & Messier 2002, Hale & Edwards 2002, Leblanc et al. 2005, Mcfarlane 2011, Ogilvy 2004
Underexposed by -2 EVs to reference within forest	1	Kato & Komiyama 2000
Underexposed by -1 EV to reference within forest	1	Rich 1989
Underexposed by -0.7 EVs to reference within forest	1	Jarcuska et al. 2010
2-3 EVs overexposed in reference to open land	11	Bolibok 2010, Clearwater et al. 1999, Van Gardingen et al. 1999, Macfarlane 2007, Richardson et al. 2009, von Arx et al. 2007, Wagner & Hagemeier 2006, Wagner 1994, 1998, 2001, Zhang et al. 2005,
1–2 EVs overexposed in reference to open land	3	Chen et al. 1991, Jonkheere et al. 2004, Seidel et al. 2012
1 EV overexposed in reference to open land	2	Pekin & Mcfarlane 2009, Schwalbe et al. 2009
Same exposure as reference in open land	3	Ishida 2004, Matsuyama et al. 2003 (in Yamamoto et al. 2010), Yamamoto et al. 2010
Posterior correction of photographs using image manipulation software	1	Stohr & Bilhimer 2008
No statement	20	Adamek et al. 2009, Bataglia et al. 2002, Buddenbaum & Seeling 2008, Clark & Murphy 2011, Danson et al. 2007, Hardy et al. 2004, Hu et al. 2009, Khabba 2009, Kidd & Chapman 2011, Lovell et al. 2003, Mengesha et al. 2005, Morsdorf et al. 2006, Nobis & Hunziker 2005, Promis et al. 2009, Ramos & Santos 2006, Rhoads 2004, Rianno et al. 2004, Rossini et al. 2006, Van Pelt & Franklin 2000, Zhao et al. 2011

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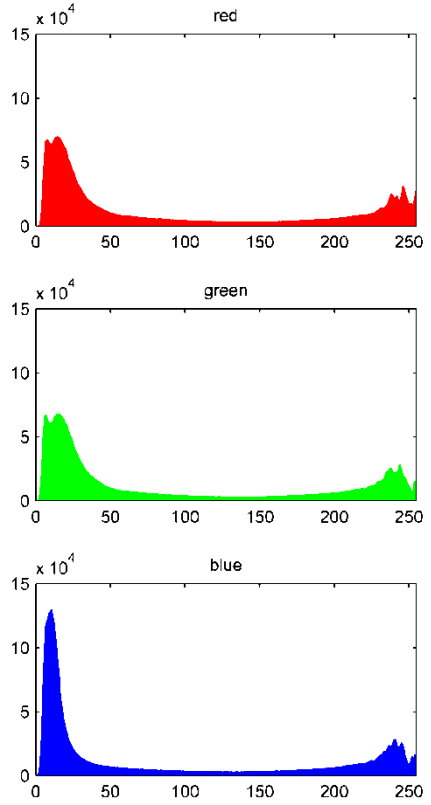
Baekshafer et al. 2013

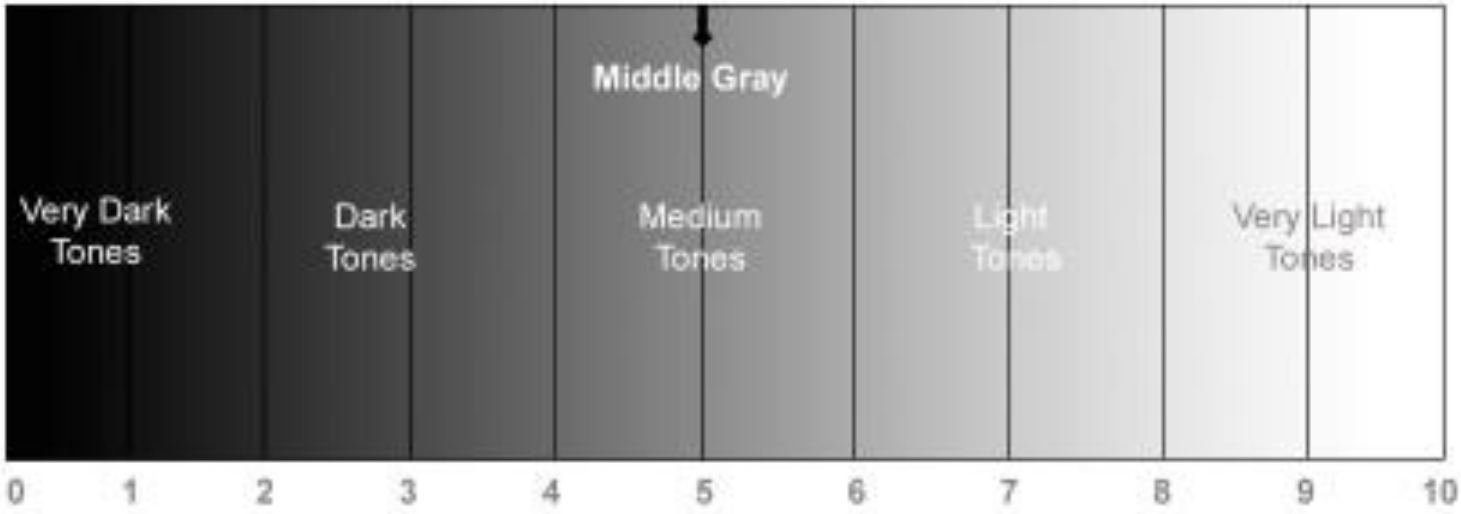
What is IDEAL exposure?

- We want to maximise contrast - Dark canopy on the left of the histogram and bright sky on the right.



What is IDEAL exposure?

- The camera wants everything to be mid-gray - Automatic exposure will darken bright scenes (dominated by sky) and brighten dark scenes (dominated by canopy).



Can we standardise exposure by shooting RAW?

- Take 12+ bit data from blue channel in RAW file.
- Import to MATLAB as 16 bit TIF/DNG/PGM.
- Contrast stretch in 16 bit space.
- Convert to 8 bit.
- Save as JPG

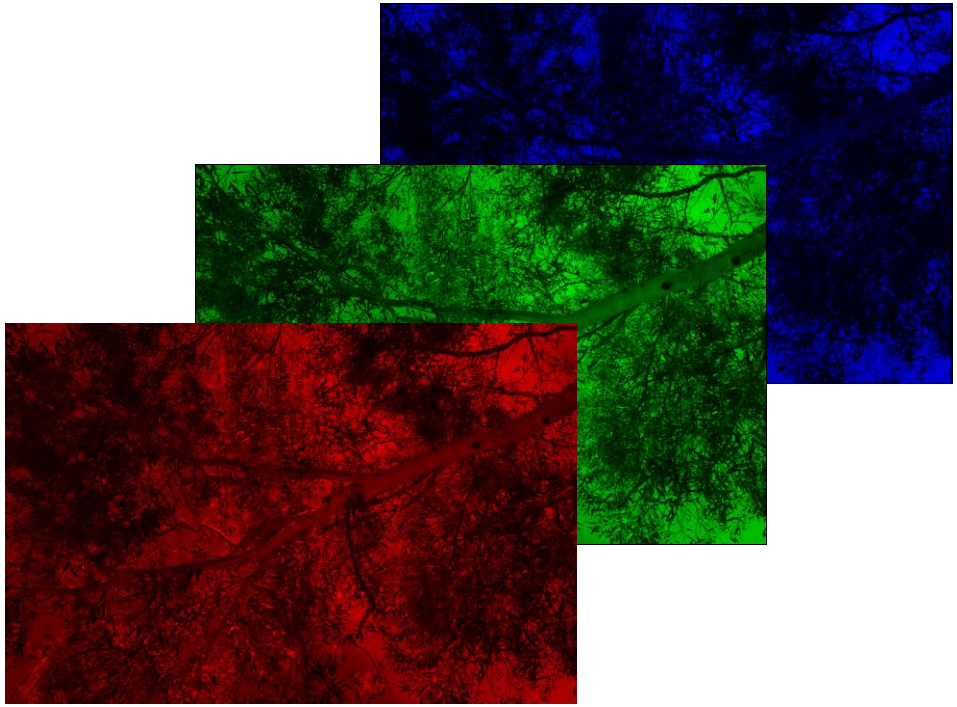
A little bit about bits

- JPEG image typically 24 bit = 3 × 8 bit.
- 8 bits = 0-255 (black 00000000 to white 11111111).

24bit RGB image

=

3 × 8bit colour channels



A little bit about bits

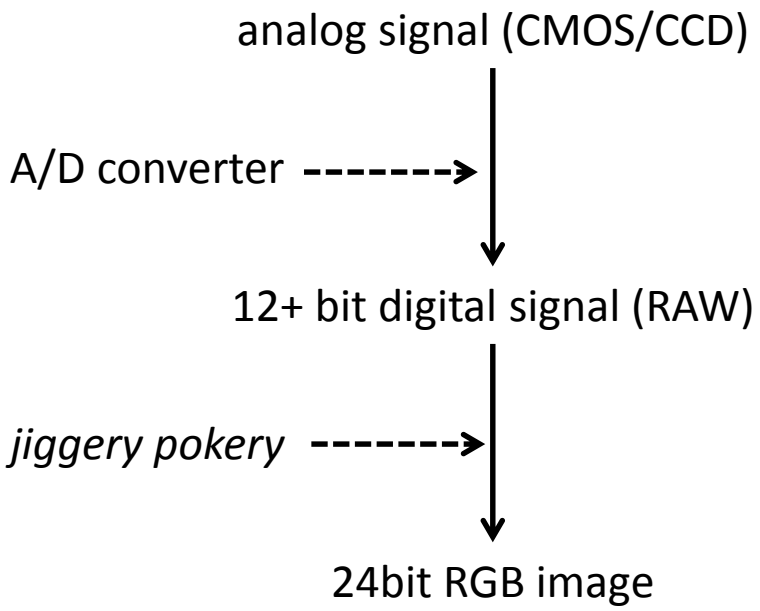
- JPEG image typically 24 bit = 3 × 8 bit.
- 8 bits = 0-255 (black 00000000 to white 11111111).
- blue channel preferred for canopy analysis.

blue

red

A bit more about bits

- camera A/D convertors are 12+ bits per channel.
- 12 bits = 0-4096 (black 000000000000 to white 111111111111).



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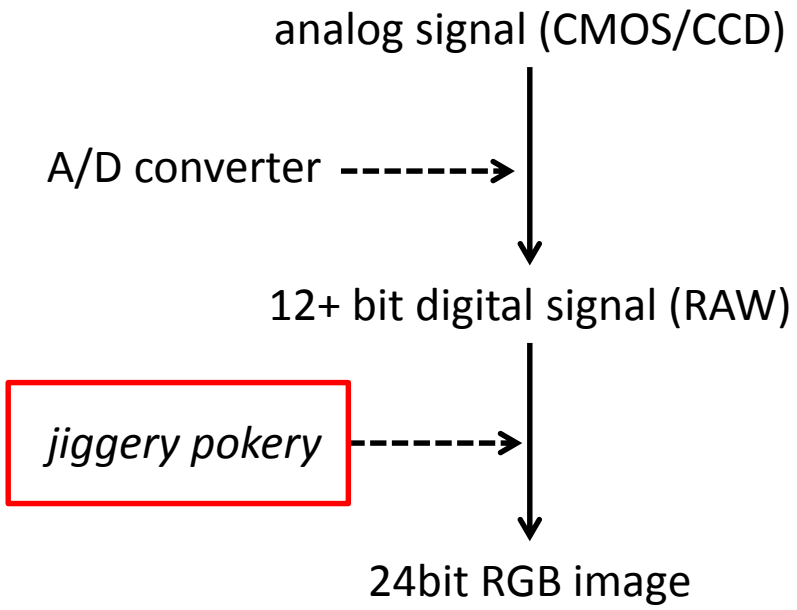

JPG = Jiggery Pokery Graphics

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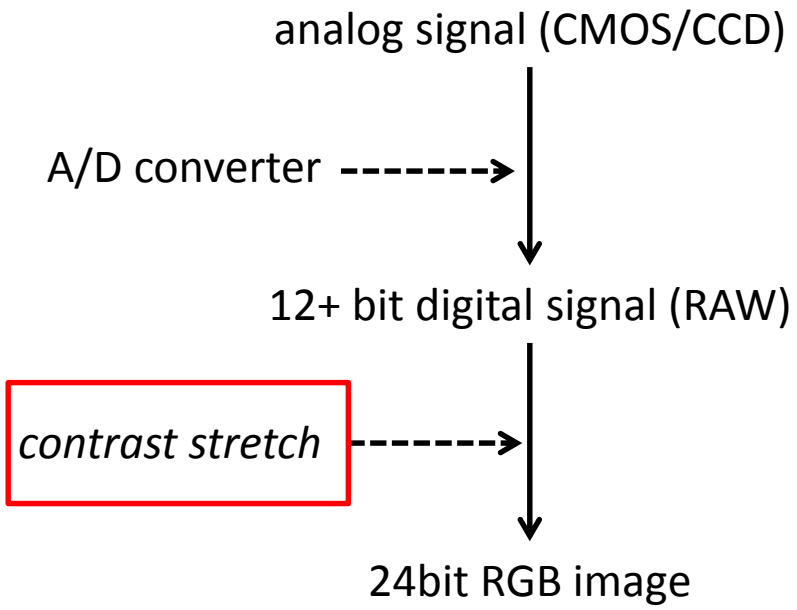
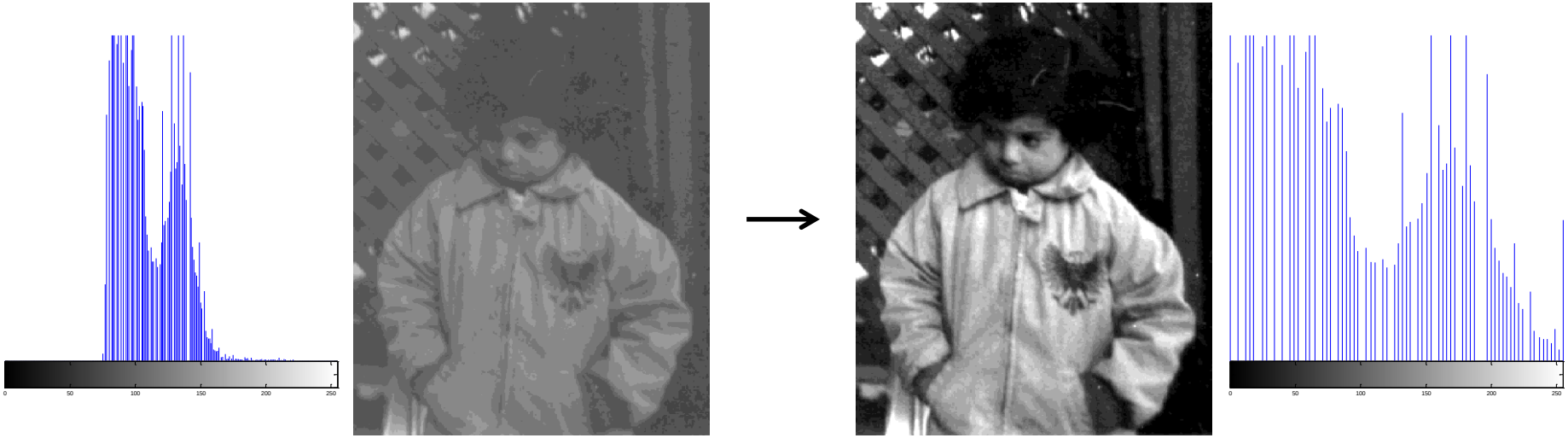


What's a contrast stretch?

- aka *normalisation*, *histogram stretch*, *dynamic range expansion*.
- image enhancement technique that attempts to improve the **contrast** in an image by '**stretching**' the range of intensity values it contains to span a desired range of values, e.g. the full range of values that the image type allows.



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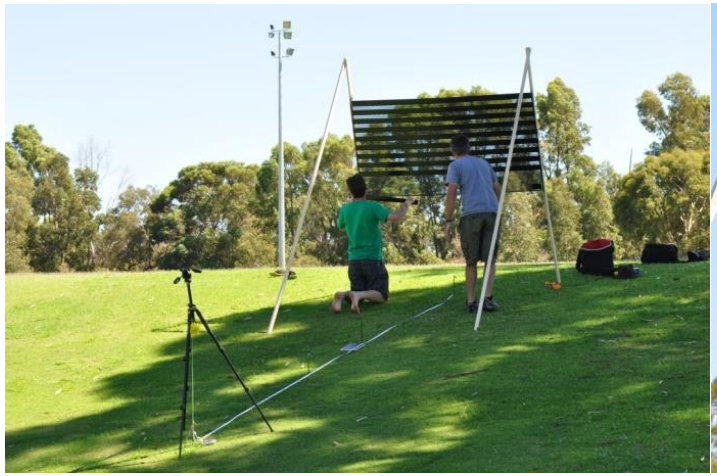
- Convert to 8 bit.
- Save as JPG

image files are typically 8 bit, 16 bit, 32 bit, 64 bit…

Test apparatus and experimental design

- A black perforated screen with known ***gap fraction***.
- Vary gap size by varying camera distance from the screen (1-5m).
- Vary gap fraction (0.06-0.40) by covering holes with gaffa tape.
- Vary exposure from +2 to -5.

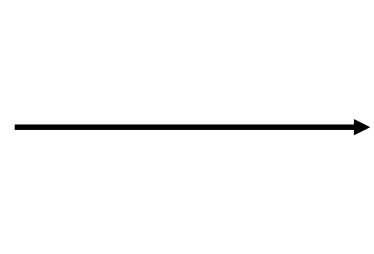


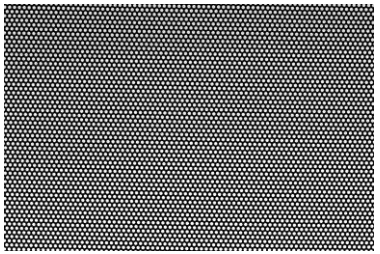
Test equipment

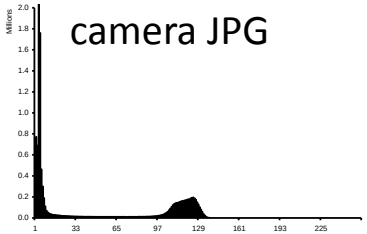
- Cover photography not fisheye photography.
- Nikon D90 DSLR camera body.
- Tamron 90mm lens – short telephoto.
- ISO-200 – native ISO for low noise.
- Small aperture (*f* 16) for good depth of field.
- Aperture priority mode – allow camera to set shutter speed.
- noise reduction off.
- sharpening off.
- everything OFF.

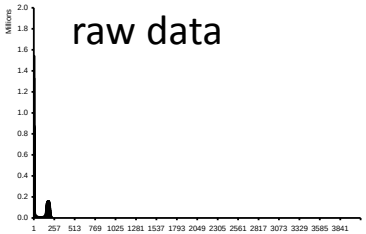
Examples

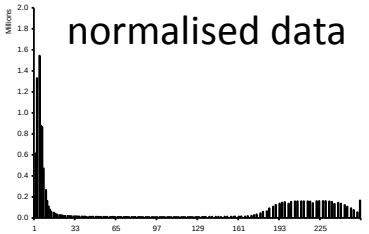
under-exposed
by 5 stops



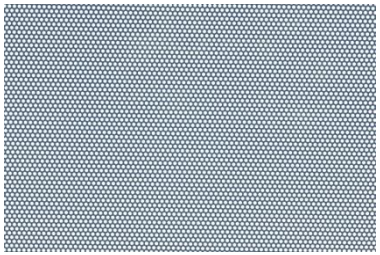


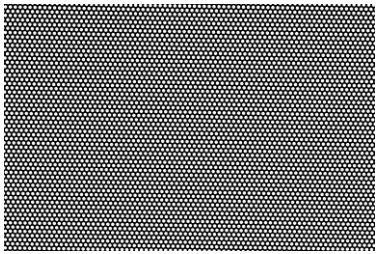


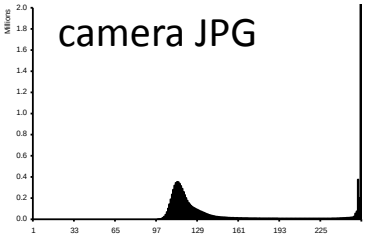


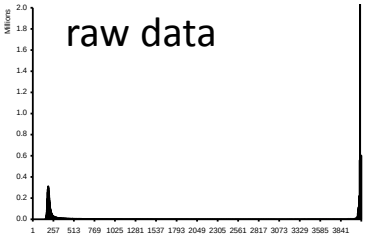


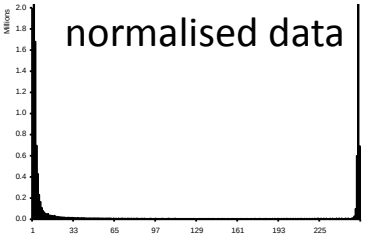
over-exposed
by 2 stops





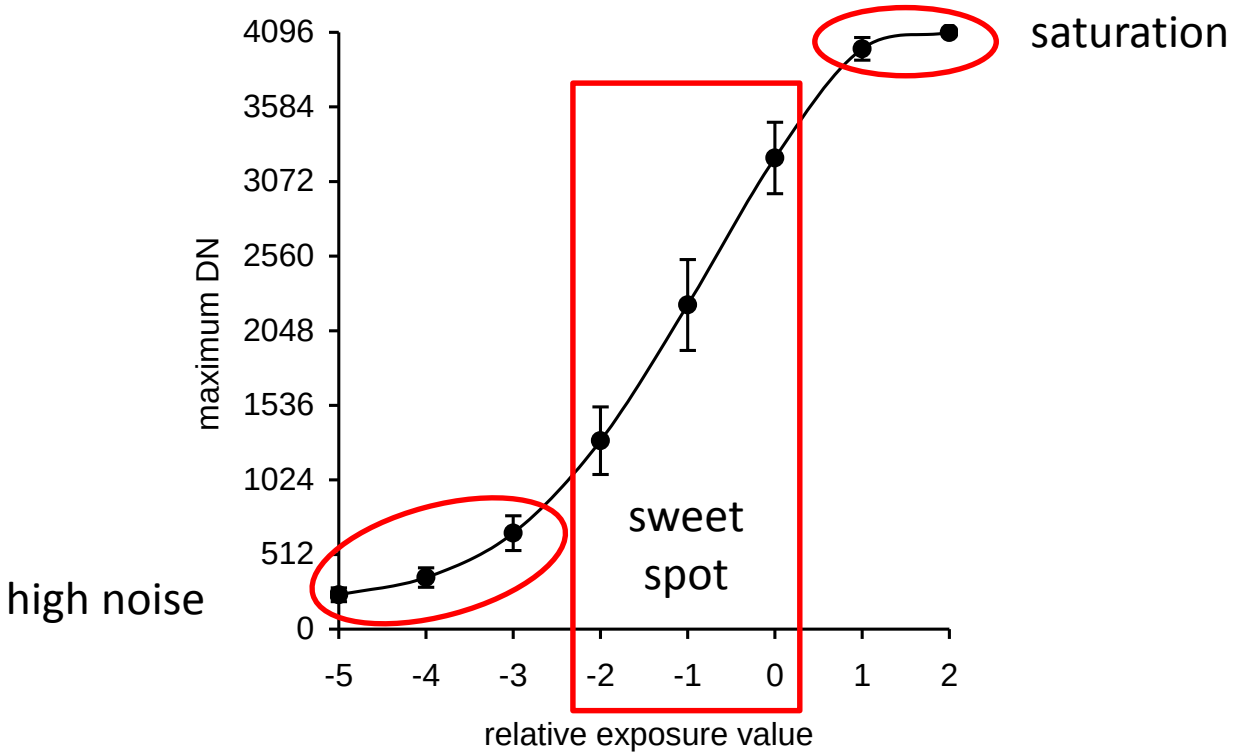






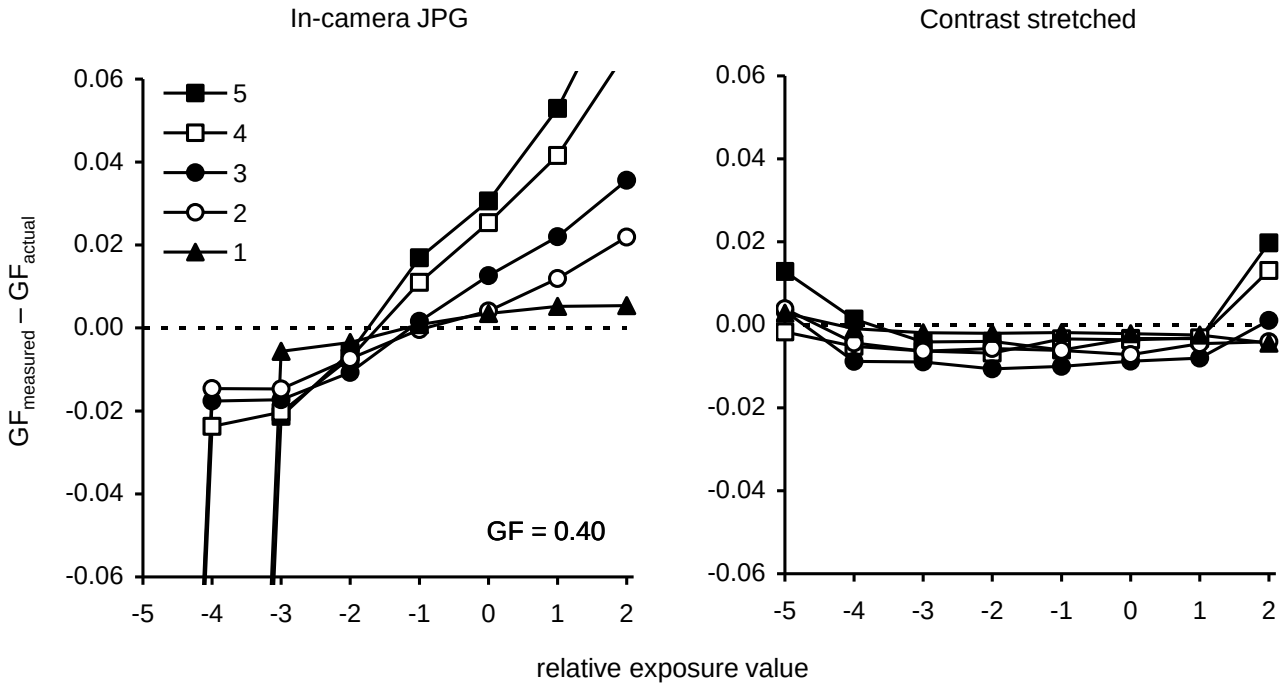
Useful range of exposure

- two stops under-exposed (-2) to auto-exposure (0), metered 'beneath the canopy'.
- based on maximum DN in each of 15 images at each REV.



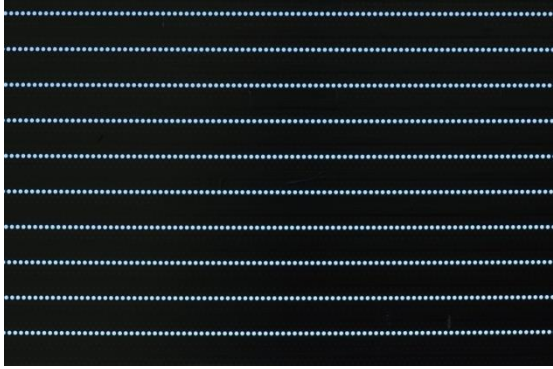
Large gap fraction (0.4)

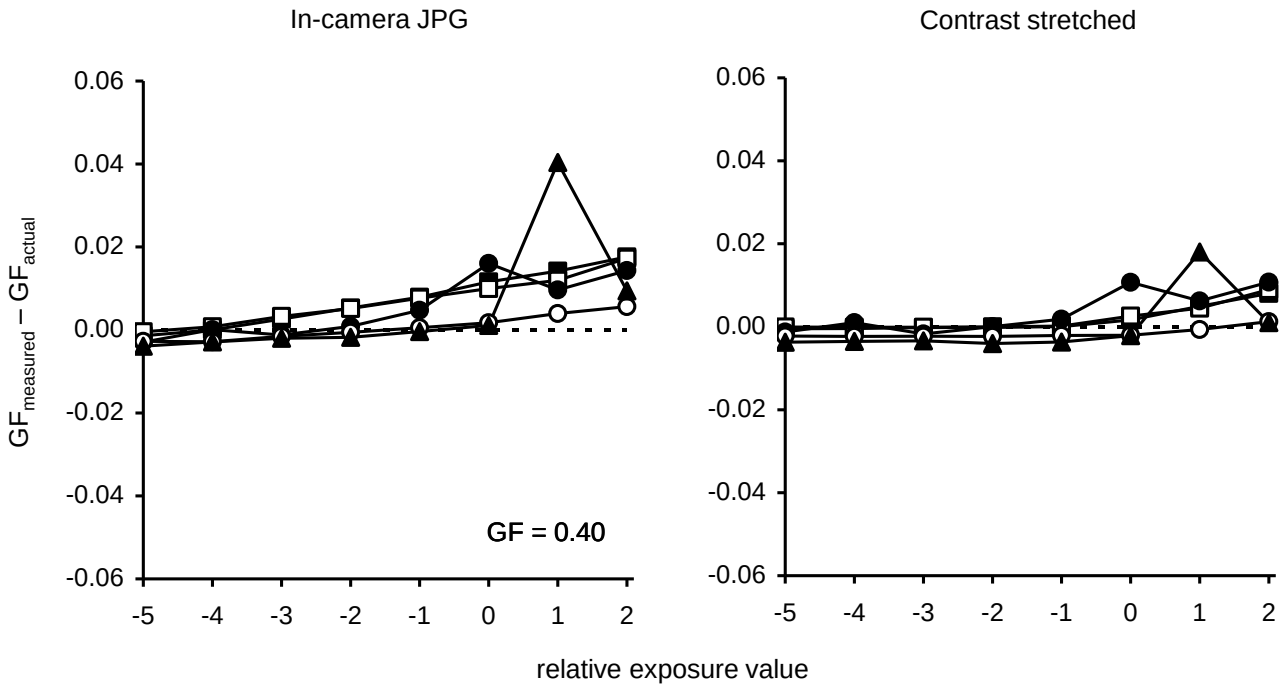
- GF from in-camera JPG very sensitive to REV; especially when gaps were small.
- optimal rev for in-camera JPG dependent on gap size.



Small gap fraction (0.06)

- GF from in-camera JPG less sensitive to REV; mainly when gaps were small.





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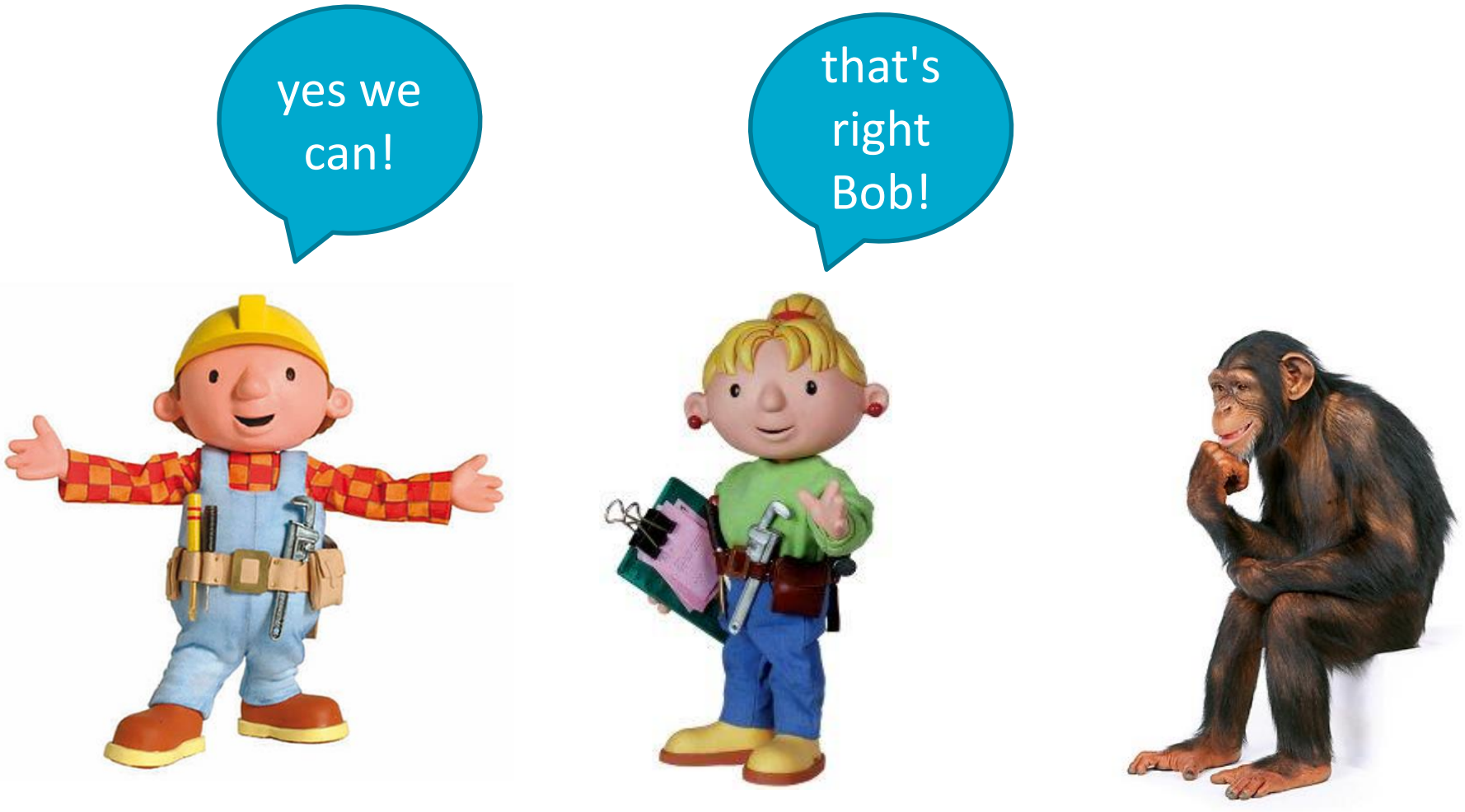

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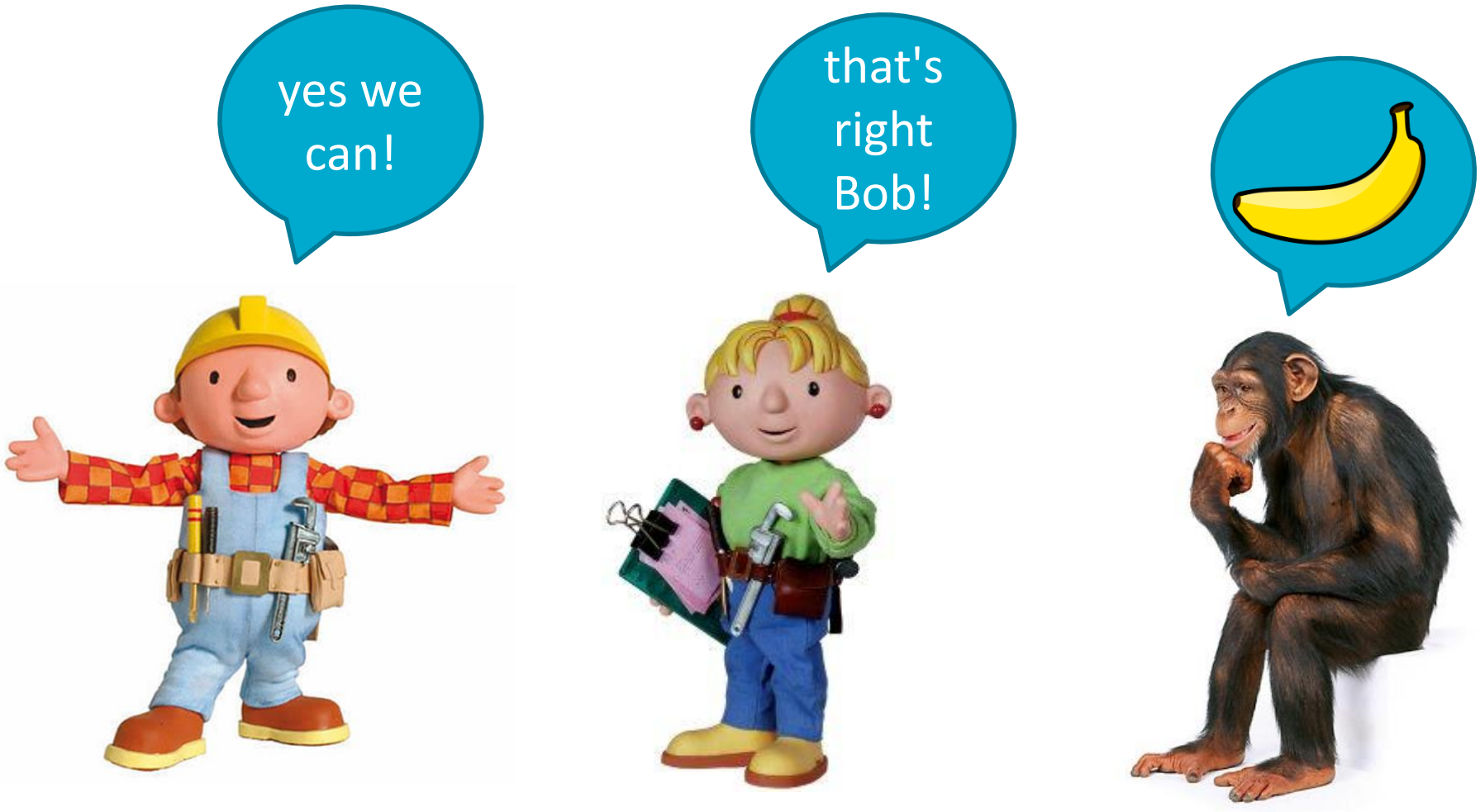
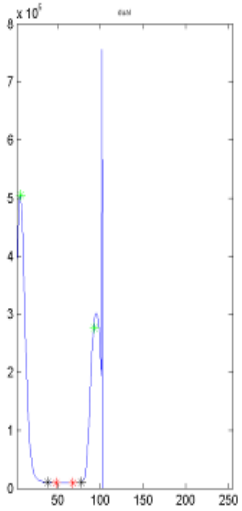


Is exposure really the problem?

- NO – just making the image darker doesn't change the answer.

-3



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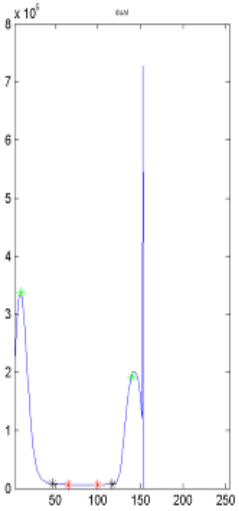
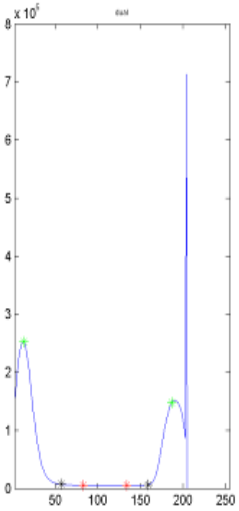
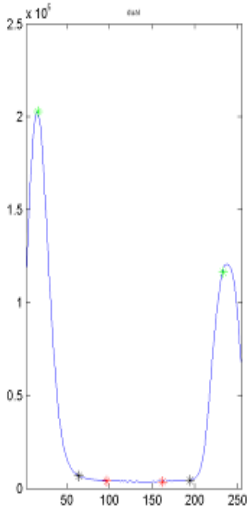


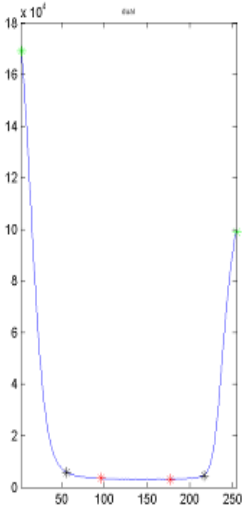
-1



0

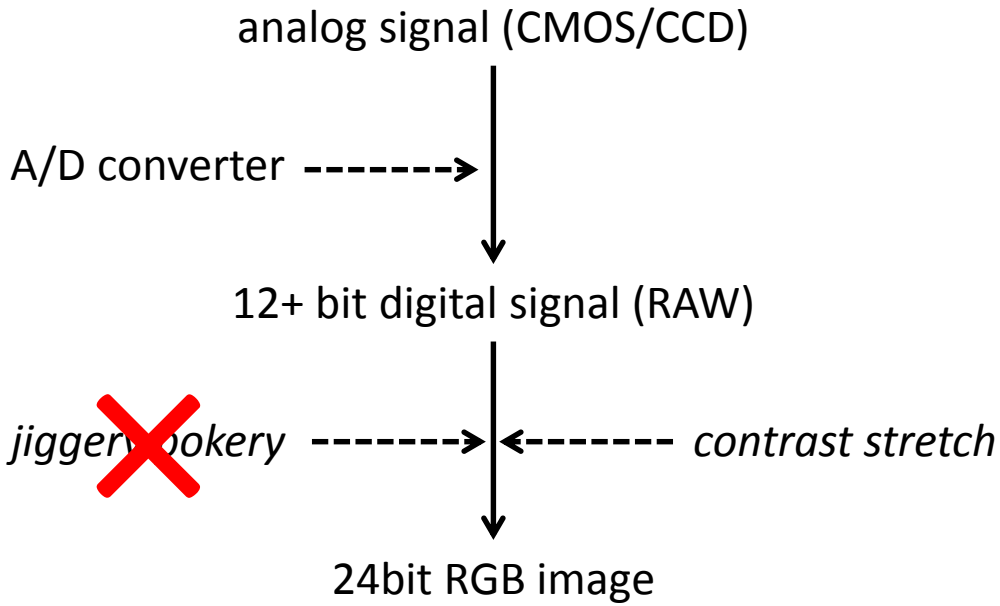


+1



- It's the interaction between exposure and *jiggery-pokery* that causes the problem.

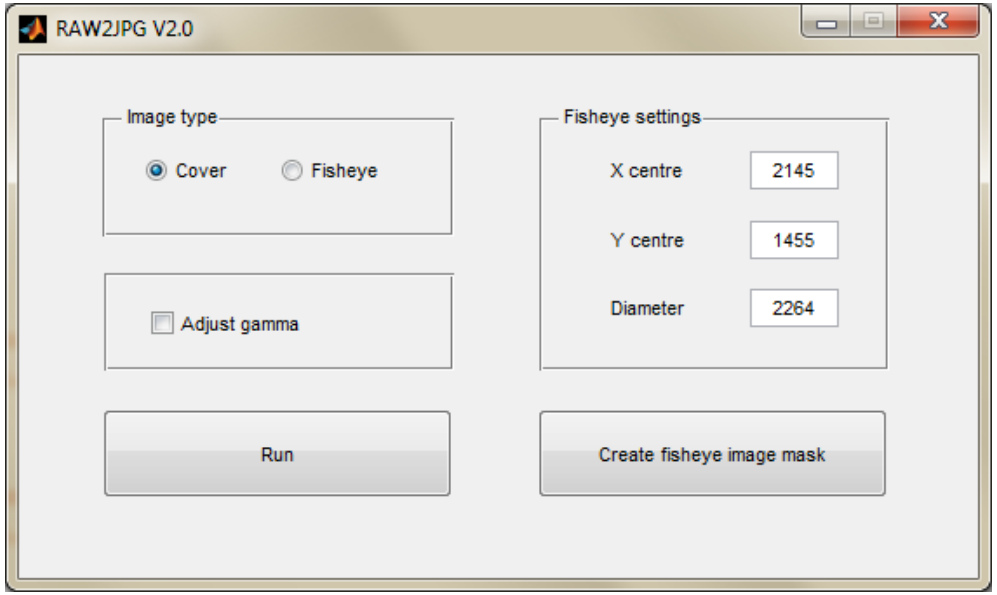
RAW *actually* solves the jiggery-pokery problem



- Contrast stretching also makes classification easier by ensuring dark and light pixels are at extremes of histogram.
- Consistent and objective – no user input/judgement.
- Clouds?

And it's easy

- Free app that takes any camera raw image and converts to pgm format (via dcraw.exe), performs the contrast stretch and saves the result as a JPEG.
- Also creates a mask for fisheye images if needed.



Conclusion

- Shoot RAW.
- Under-expose by 1 stop.
- Use blue channel.
- Contrast stretch in 16 bit space.
- Save as JPG.

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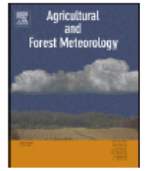

Digital canopy photography: Exposed and in the raw

Craig Macfarlane[a,*], Youngryel Ryu[b,c,d], Gary N. Ogden[a], Oliver Sonnentag[e]

[a] CSIRO Ecosystem Sciences, Private Bag No. 5, Wembley, WA 6917, Australia
[b] Department of Landscape Architecture and Rural Systems Engineering, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, Republic of Korea
[c] Interdisciplinary Program in Agricultural and Forest Meteorology, Seoul National University, Republic of Korea
[d] Interdisciplinary Program in Landscape Architecture, Seoul National University, Republic of Korea
[e] Université de Montréal, Département de géographie, Montréal, Québec H2V 2B8, Canada

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ABSTRACT

Estimates of the canopy gap fraction, on which calculations of leaf area index (LAI) are based, are sensitive to photographic exposure in upward-facing images. In this article we describe a simple, automated method of image acquisition and processing that eliminates both subjectivity and the need for the operator to consider photographic exposure in the field. A key strength of our methodology was the use of a test apparatus (perforated aluminum screen) with a precisely known gap fraction; this allowed us to separate the confounding effects of gap size and gap fraction on the optimal photographic exposure for a canopy. We took photographs of the test apparatus at different photographic exposures; we varied the gap fraction by covering a proportion of the holes in the screen, and also varied gap size by varying the distance of the camera from the screen. We acquired both raw images and JPEG images. We found that the optimal exposure of JPEG images varied with both gap size and gap fraction, not just gap fraction as previously assumed. Underexposing by one stop yielded raw data that were never clipped resulting in data loss, but that used most of the 14-bit range of the raw file. We also found that it was easily possible to standardize photographic exposure during image processing by acquiring raw images in the field; thus eliminating the variation in estimated gap fraction and LAI associated with exposure variations. This result was replicated in both fisheye images and cover images that we acquired in real canopies. We recommend the following protocol for acquiring canopy images in future studies:

1. Shoot raw using one stop of underexposure.
2. Convert propriety-format raw files to DNG format using the free software Adobe DNG Converter.
3. Contrast stretch the blue channel of the image and save as JPG for further analysis. The authors can supply MATLAB script to perform this step.

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Why photography?

- Permanent record – QC and chance to reanalyse
- Flexible method – one camera, many lenses
- Familiar technology – easy to teach
- Cheap – technology starts at around AUD$500; lots of free software

A flexible method

Circular Fisheye Image.
Full 0-180° field of view.
Low resolution.
Poor vertical sampling.
Large effective plot size per image.
Used to estimate LAI and openness.

Full-frame Fisheye Image.
0-180° field of view across diagonal.
Medium resolution.
Poor vertical sampling.
Medium effective plot size per image.
Used to estimate LAI and openness.

Cover Image.
0~30° field of view.
Very high resolution.
Excellent vertical sampling.
Small effective plot size per image
Used to estimate cover, crown porosity and LAI.

Circular 57.5° image.
~55-60° field of view.
Low resolution.
No vertical sampling.
Medium effective plot size per image.
Used to estimate LAI.

Pekin and Macfarlane 2010

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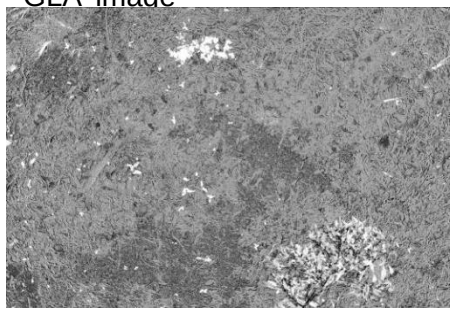
Very high resolution.
Excellent vertical sampling.
Small effective plot size per image
Used to estimate cover, crown porosity and LAI.

Circular 57.5° image.
~55-60° field of view.
Low resolution.
No vertical sampling.
Medium effective plot size per image.
Used to estimate LAI.

Pekin and Macfarlane 2010

RGB image

GLA' image



classified image: cover = 0.04

Macfarlane and Ogden 2012

Cheap and familiar (and cool)

Fuentes et al. 2012

Figure 3. Settings menu showing options for the gap fraction threshold, image sub-division options and to enable/disable the location services from the device.

Figure 2. This figure (left) shows the icon of the app as seen in the iPhone 4S. The figure on the right corresponds to the app and the main menu with the home, new measurement, settings, how to use it and about pages.

Key steps

Image capture

Image processing → B&W BITMAP → Simple maths → Gap fraction → Fancy maths → LAI