Camera Identification Using Sensor Pattern Noise as a Fingerprint

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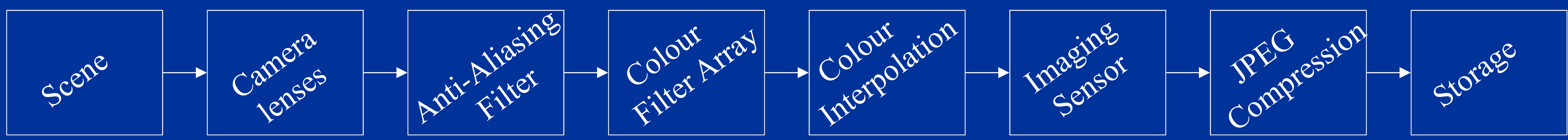
What is sensor pattern noise and where does it come from?

The Sensor Pattern Noise is defined by Lukáš and Fridrich[1] as any noise component that survives frame averaging. What this means is that given many images, the pattern noise will still be present after averaging all the images. In fact by averaging many images we achieve an almost complete suppression of detail and random noise and an enhancement of the pattern noise.

The Sensor Pattern Noise consists of two main components; The Fixed Pattern Noise (Or Dark Current) and the Photo-Response Non Uniformity (PRNU) Noise. PRNU noise can be further broken down to pixel non-uniformity (PNU) noise and a random element. To understand how this noise occurs you must understand the processes within a digital camera:



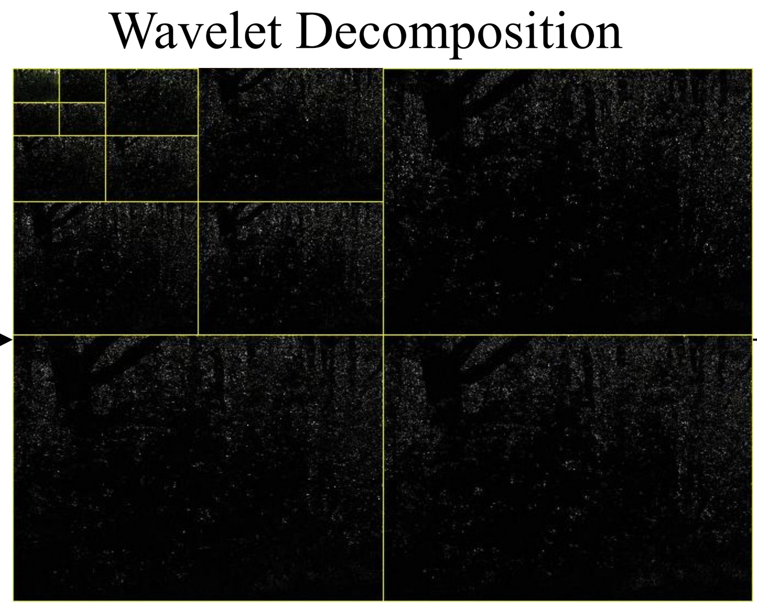
Noise in the resultant image is caused partially by the colour filter array and the interpolation algorithm but primarily in the Imaging Sensor. The pattern noise is present whether the imaging sensor is a Charge-Coupled Device (CCD) or a Complementary Metal-Oxide-Semiconductor (CMOS). The PRNU noise is caused by pixel non-uniformity (PNU), which could also be described as the different sensitivity to light observed in each pixel, due to the inhomogenity of silicon wafers and imperfections in the manufacturing process of the sensor. As well as the PNU noise, light refraction on dust particles and optical surfaces also contribute to the PRNU noise. These are usually filtered out due to their random nature.

How do we extract the pattern noise from an image?

If you consider that an image is essentially the scene plus an additional noise component, extracting the noise is a case of subtracting the original scene from the saved image. To retrieve an approximation of the scene we use a de-noising filter.[2] The de-noising filter used, designed by Mihcak, Kozintsev and Ramchandran, uses the wiener filter applied to 4 levels of a wavelet decomposition.

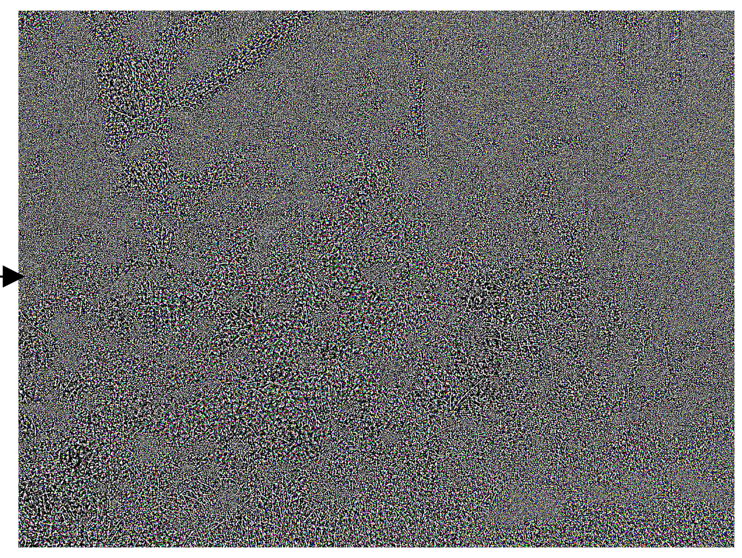
Original Image

Wavelet Decomposition



De-noised Image

Pattern Noise



In order to use the pattern noise, we must generate some reference patterns from various cameras. To generate a reference pattern we start with a large volume of plain, evenly lit images. After extracting the pattern noise from each of these images, we take the average of all the images.

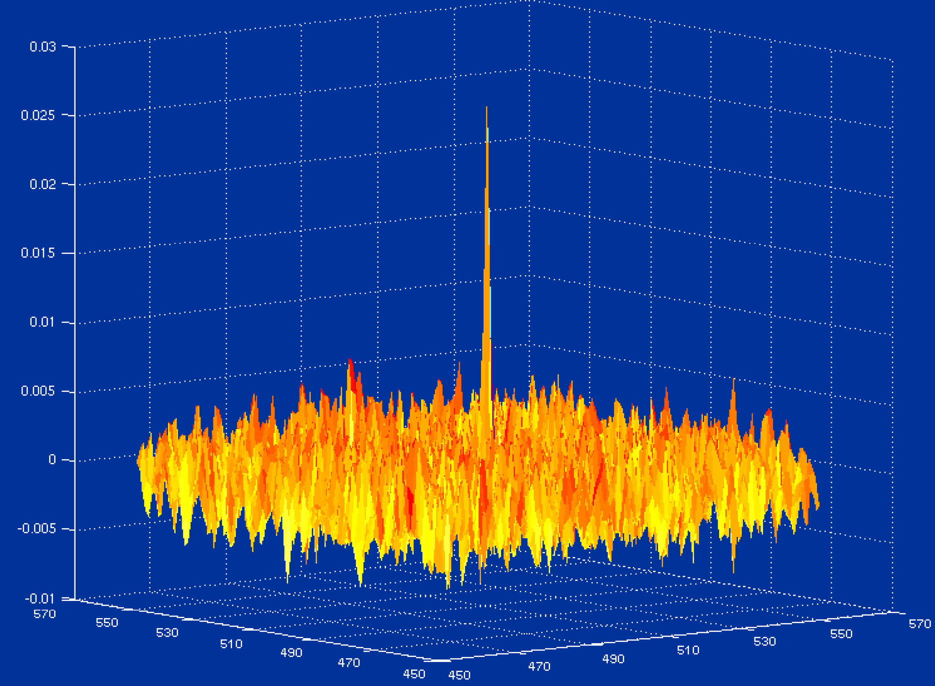
It is ideal to use either an evenly lit light-box or pictures of a blue sky for generating the reference patterns. The more images used, the more random noise is suppressed while there PRNU noise is amplified.

How do we achieve a positive identification?

After generating some reference patterns for various different cameras, we can start identifying images. Unfortunately, due to the method used in generating the pattern noise, we cannot just compare the image to the reference pattern and give a definitive yes or no answer. Instead we calculate the correlation between the images. Given that the image may have been cropped, a Normalised Cross Correlation (NCC) function is used to generate a matrix of the correlation at different points. Taking the maximum value of the matrix will give us the best correlation possible with a reference pattern. A correct identification is usually achieved with a maximum cross correlation of 2% or above. Despite how low this figure seems, an incorrect identification will typically have a value below 0.1%. The NCC function used is:

$$NCC[s_1,s_2] = \frac{\sum_{k=1}^{m}\sum_{l=1}^{n}(X[k,l]-\bar{X})(Y[k+s_1,l+s_2]-\bar{Y})}{\|X-\bar{X}\|\|Y-\bar{Y}\|}$$

In the NCC function, s_1 and s_2 are the cropping co-ordinates of the smaller image and X and Y are the image and the reference pattern respectively. Running this function on an example and graphing the resultant correlation matrix should produce a graph like this:



In the graph the spike is at the location (512,512) indicating that it best correlates at those co-ordinates. The correlation of 2.5% suggests a correct identification with the reference pattern.

References

[1] J. Lukáš, J. Fridrich, M. Goljan, "Digital Camera Identification from Sensor Pattern Noise" in *IEEE Transactions on information forensics and security,* vol. 1, no. 2, June 2006, pp 205-214

[2] M. K. Mihcak, I. Kozintsev, K. Ramchandran, "Spatial adaptive statistical modelling of wavelet image coefficients and its applications to de-noising," in *Proc. IEEE Int. Conf. Acoustics, Speech, Signal Processing*, Phoenix, AZ, Mar. 1999, vol. 6, pp. 3253-3256

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