Practical Method to Derive Non-Linear Response Functions of Cameras for Scientific Imaging

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We developed a practical method to derive response functions which convert the amount of incident light to the A/D counts of cameras for scientific imaging [1]. Some cameras do show non-linear responses, and we have to know them to carry out photometric analysis with the data taken by such cameras. We applied this method for an InGaAs near-infrared camera, XEVA-CL-640 (XENICS), and succeeded to derive a response function, even though it was complicated non-linear one. In principle, such response functions can be derived from the output A/D counts, S, measured at various incident light levels, I, which are accurately controlled over the whole dynamic range. However, it is not easy to actually do such measurements with high accuracy. Then we developed a new practical method to derive non-linear response functions. In this method, we need a mechanism to accurately control the amount of incident light into cameras just within a limited dynamic range and at a limited number of steps (relative light level T, which may be exposure time, transparency, etc.). A variable brightness light source (brightness B), which supplies the incident light into cameras, is also necessary, but we do not need to know its accurate brightness.

Figure 1(a) shows the raw results measured under such conditions; output A/D values, S, are measured at several T's under various unknown B's (the brightness of the incident light, I, is written as $I = BT$). It seems that without knowing B's, it is difficult to derive the relation between I and S from the results shown in Figure 1(a). However, we can derive IdS/dI, because the relation $dI = BdT$ based on $I = BT$ brings $dS/dT = BdS/dI$, and this means $TdS/dT = TBdS/dI = IdS/dI$. The value TdS/dT can be derived from the known values, T and S, and therefore, without knowing B, we can derive a unique relation between T and $TdS/dT(= IdS/dI)$ as shown in Figure 1(b). The relation seen in Figure 1(b) can be converted to the relation between I and S through the numerical integration. Figure 1(c) shows the derived relation between I and S, namely the response function of the camera. Obviously the function is non-linear. Figure 1(d) shows a close-up of the low-light level portion of Figure 1(c), and we can find a complex non-linear behavior.

We are using a XEVA camera for the polarimetry of the infrared solar light, which requires high accuracy measurements. Compensation of the non-linearity based on the derived function works well, and we have quantitatively high-quality observational data.

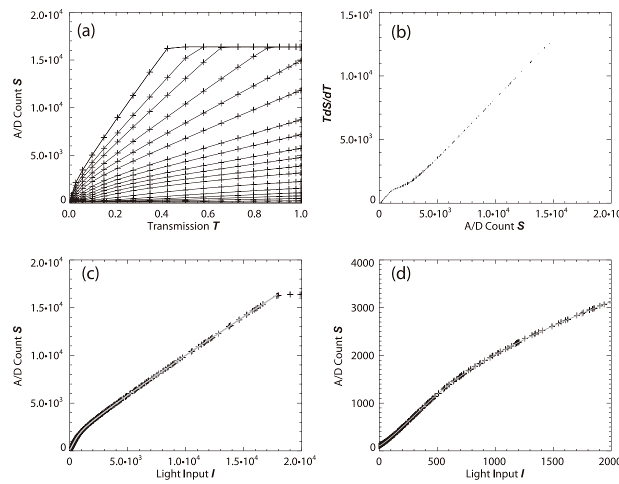

Figure 1: (a) Measured A/D counts S at various values T are shown with plus signs. Each line represents the measurements carried out under the same brightness B of the light source. (b) Relation between the measured A/D count, S, and the TdS/dT value. All the measured points are on a unique curve, regardless of the values of B. (c) Calculated non-linear response function between the amount of light input, I, and the output A/D count, S, is shown with a solid grey line. The measured points shown in Figure 1(a) are also plotted with plus signs. (d) Enlargement of the low-I range of panel (c).

Reference

[1] Hanaoka, Y., Suzuki, I., Sakurai, T.: 2011, *App. Opt.*, **50,** 2401-2407.