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Method of shots modeling using noises and radiometric parameters of registering cameras

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Abstract

Method of modeling of shots registering is demonstrated. The method takes into account noise and radiometric parameters of used photo- and videocameras. The method was tested using different characteristics of cameras. Estimates of the signal-to-noise ratios of modeled shots were obtained.

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Keywords: shots modelling; temporal noise; spatial noise; radiometric function; dynamic range; photosensor; camera; signal-to-noise ratio; image.

1. Introduction

Noises and dynamic range limitation of photo- and videocameras are among the most important constraints in different scientific and technical tasks [Gonzalez et al. (2007), Theodoridis et al. (2009), Cheremkhin, Evtikhiev et al. (2014, Proc. SPIE), Soifer et al. (2002), Soifer (2002), Wang et al. (2004), Wang et al. (2002), Schnars et al. (2015), Cheremkhin, Evtikhiev et al. (2014, J. Phys.: Conf. Ser.), Ramirez (2011), Mayer et al. (2012), Paragios et al. (2006), El Gamal et al. (2005)] and consumer applications [El Gamal et al. (2005), Keelan (2002)]:

- image encryption [Gonzalez et al. (2007), Theodoridis et al. (2009), Cheremkhin, Evtikhiev et al. (2014, Proc. SPIE)];
- diffraction optics [Soifer et al. (2002), Soifer (2002)];

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- image compression [Gonzalez et al. (2007), Wang et al. (2004), Wang et al. (2002)];
- digital holography [Schnars et al. (2015), Cheremkhin, Evtikhiev et al. (2014, J. Phys.: Conf. Ser.), Ramirez (2011)];
- tomography [Mayer et al. (2012)];
- optical flow [Paragios et al. (2006), El Gamal et al. (2005)], and etc.

For example, quality of the digital holograms reconstruction is defined by the factors including camera's characteristics [Evtikhiev et al. (2013)]. And for digital holography applications, knowledge of expected quality of reconstruction is required. This will assess the impact of camera's parameters on the reconstruction. Also it will allow to definefield of application that are solved by the cameras of different types. A method of modeling of shots using noise and radiometric characteristics of the cameras briefly were describes in [Evtikhiev et al. (2013)]. But it was applied only to the reconstruction of digital Fresnel holograms.

In this report, the method was tested not only using digital holograms but also images of any content. To simulate the registration process we use previously measured characteristics of cameras of various types.

2. Description of the method of shots modelling

Noises of digital photo- and videocameras can be divided into two main types: random and pattern. Temporal noise is random while spatial noise also known as pattern noise is constant [El Gamal et al. (2005), Holst et al. (2011), Janesick (2007)].Temporal noise can be divided into dark and light components. Dark temporal noise is firstly due to pixel's charge fluctuations without illumination. Photon shot noise is the main component of the light temporal noise. Spatial noise is due to dissimilarities of characteristics of camera's photosensor pixels. This type of the noise does not depend on time. It can be caused by different factors: inhomogeneity of refractive index of pixels and etc. Spatial noise can be divided into two components also: photo response and dark signal non-uniformities. Also it should be noted that usually spatial noise is about 0.5 % of camera signal value and 2-4 times less than temporal noise [The European Machine Vision Association (2015)].

Modeling of dependency of noise value $\sigma_\Sigma(S)$ on pixel's signal value S was performed as follows [Cheremkhin, Krasnov, Kurbatova, et al. (2014)]:

$$\sigma_\Sigma(S)=\sqrt{(\sigma_{dt})^2+(\sigma_{lt})^2+(\sigma_{ds})^2+(\sigma_{ls})^2}=\sqrt{(\sigma_{dt})^2+\frac{S}{C}+(DSNU)^2+(PRNU*S)^2}, \quad (1)$$

where

$$\sigma_{lt}=\sqrt{\frac{S}{C}}, \quad (2)$$

$$\sigma_{ds}=DSNU, \quad (3)$$

$$\sigma_{ls}=PRNU*S, \quad (4)$$

σ_{dt} is standard deviation (STD) of dark temporal noise (measured in digital signal numbers, DN),
σ_{lt} is STD of light temporal noise (in DN),
σ_{ds} is STD of dark spatial noise (in DN),
σ_{ls} is STD of light spatial noise (in DN),
C is camera gain constant, (the scaling constant for conversion the number of electrons into digital signal value; electrons/digital numbers, e^-/DN),
$PRNU$ is photo response non-uniformity (relative unities).