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Method of improvement of signal-to-noise ratio of registered shots using dark and light spatial noise portraits of camera's photosensor

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Abstract

Improvement of the signal-to-noise ratio of registered frames is necessary in scientific, technical and amateur tasks. Dark and light spatial noise portraits of camera's photosensor can be used for frames quality increase. Earlier method of improvement of the signal-to-noise ratio of shots by use of light spatial noise portraits of camera's photosensor was proposed. In this paper method of improvement of the signal-to-noise ratio of shots by use of both light and dark spatial noise portraits was analyzed. According to the results of numerical experiments, it was found that the signal-to-noise ratio can be increased up to 50÷60 times compared to that one of a single image.

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Keywords: signal-to-noise ratio; light spatial noise portrait; dark spatial noise portrait; photosensor; camera; image; frame.

1. Introduction

Improvement of quality of registered frames is important in different scientific fields: image encryption [Theodoridis et al. (2009), Kumar et al. (1997), Duda et al. (2001)], digital holography [Juptner et al. (2005), Evtikhiev et al. (2013, J. Opt. Technol.), Kreis (2005), Cheremkhin, Evtikhiev et al. (2014, J. Phys.: Conf. Ser.), Barsi (2009)], diffractive optics [Soifer (2002)], etc. Decreasing of camera's photosensor noise allows to improve the shots signal-to-noise ratio (SNR). There are two types of camera's photosensor noises: temporal and spatial ones [Janesick (2007), Nakamura (2006), Cheremkhin et al. (2014, Opt. Eng.)].

For increase the image SNR, the modification of flat-field correction technique for image SNR increasing was proposed [Evtikhiev et al. (2013, Naukoemkie technologii), Evtikhiev et al. (2014)]. Unlike the sky or twilight flats

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that usually used in flat-field correction technique [Eskridge (2015)], the light spatial noise portrait (LSNP) of camera's photosensor was compensated for spatial noise elimination. LSNP is array of photosensor pixels photo response non-uniformities and commonly used for identification of camera's photosensor [Pevny et al. (2010), Popescu et al. (2005)]. This modification is aimed to spatial noise decreasing. So it is especially effective after application of others methods of SNR increasing that suppress temporal noise. We investigated numerically in [Evtikhiev et al. (2013, Naukoemkie technologii)] and experimentally in [Evtikhiev et al. (2014)] application of the LSNP compensation method in conjunction with the averaging over frames method.

In this report, we proposed to further increase of the SNR by use of dark spatial noise portrait (DSNP) of photosensor. DSNP is array of dark spatial non-uniformities of the photosensor pixels. We analyzed and investigated application of the DSNP and LSNP compensation method in conjunction with the averaging over frames method. For the numerical estimation of the SNR increase value, we used noise and radiometric characteristics of the consumer and scientific cameras.

2. Description of the modification of flat-field correction technique for SNR increasing by compensation of camera's photosensor DSNP and LSNP

The earlier [Evtikhiev et al. (2014)] proposed modification of flat-field correction technique for image SNR increasing can be described in following way. At first, several frames of a single scene are registered. Then they are averaged into a single image $I_0(x,y)$ by using the averaging over frames method. And finally compensation of light spatial noise portrait (LSNP) of camera's photosensor is applied according to following equation:

$$I(x,y) = \frac{I_0(x,y) - DSNP(x,y)}{1 + LSNP(x,y)} \quad (1)$$

where

$I(x,y)$ is obtained image with increased SNR,

$LSNP(x,y)$ is LSNP of camera's photosensor i.e. values of pixels photo response non-uniformity,

$DSNP(x,y)$ is DSNP of camera's photosensor i.e. values of dark spatial non-uniformity,

(x,y) is discrete coordinates corresponding to photosensor pixels.

Thus firstly photosensor DSNP should be compensated and only then LSNP.

3. Numerical estimation of the value of SNR increasing by spatial noise suppression using compensation of camera's photosensor LSNP and DSNP

As mentioned above we investigated application of the DSNP and LSNP compensation method in conjunction with the averaging over frames method. In this section, achievable increase of image SNR is estimated using:

- the averaging over frames method;
- application of LSNP compensation method only;
- application of DSNP compensation method only;
- LSNP compensation method in conjunction with the averaging over frames method;
- DSNP compensation method in conjunction with the averaging over frames method;
- DSNP and LSNP compensation method in conjunction with the averaging over frames method.

For obtaining of quantitative SNR estimations with Eq. (4)-(9) characteristics of two cameras were used:

- consumer camera Canon EOS 400D;
- scientific camera Megaplus II ES 11000.