Elimination of the CCD Camera Noise in Microscopic Measurements of Machine Elements

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Abstract. *In this paper the fundamental tasks of a computer measuring system incorporating a CCD camera were defined. A method for the determination and elimination of camera noise using a multiple exposition approach was shown. Some research results on the level of noise and possible impacts of noise elimination were presented.*

Keywords: CCD camera noise, microscope measurements, dimensional metrology

1. Introduction

Camera-computer integration makes it possible to replace the observation of an object in the ocular for its more convenient observation in the visual display unit. This measurement approach has been known for many years now. This type of measuring techniques is targeted now for specified models of microscopes and towards some specified measuring tasks, and therefore lacks universality.

The Metrology and Quality Testing together with the Computer System Architecture Groups of the Wroclaw University of Technology have developed (as a joint project) a universal, teaching and research oriented test stand for the microscopic measurements of machine elements (Fig. 1). A large measuring microscope equipped with digital systems for the measurements of displacements of the measuring table and a CCD camera interfaced with the optical system of the microscope were employed.

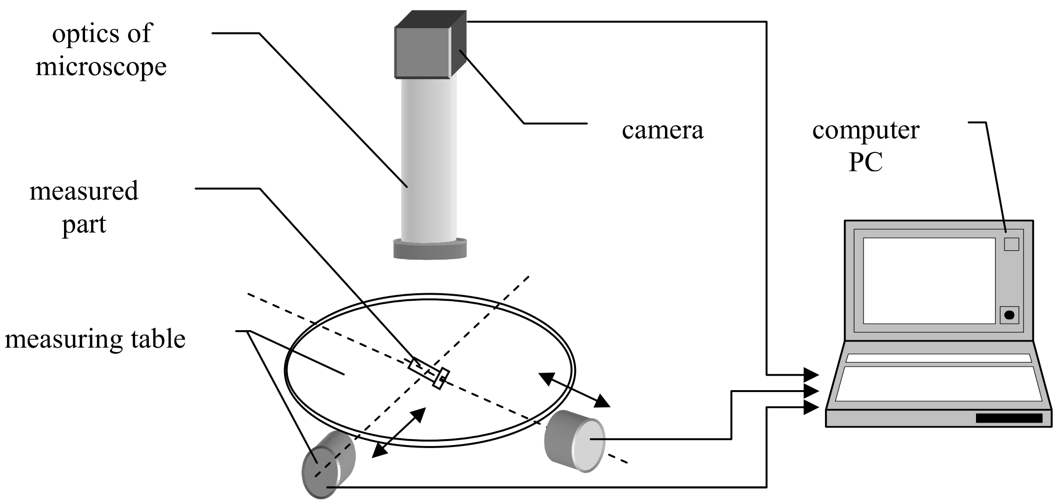

Fig. 1 Scheme of the measuring stand

The measuring stand is linked to an IBM PC computer, which was provided with a video chart and a dedicated "Video Measurement" software. The programme establishes the matrixes of distances and angles based upon the graph of the observed image pixels, which permits to evaluate the geometry of the measured object. Some of the implemented image processing tasks are the determination of contour, of negative, contrast, zoom, and rotation.The fundamental problems of information processing, apart of the optical system faults, stem from the camera and the related noise of the vision signal. It is of crucial importance on the quality of further image processing and consequently, on the accuracy of geometrical form measurements. The elimination of noise impact and other correctional measures result in the improved image quality and make it possible to obtain an unambiguous and accurate identification of the individual features of the observed object.

2. Reasons of camera mapping errors

Video generated images are not free of different types of defects and distortions which stem from the quality of the electronic materials used in the construction of the camera.
These faults are:

- Distortions of some fragments of the image which are due to errors in its description by individual pixels.
- Truncated image (at the top or bottom).
- Difference in the brightness gradients.
- Eigen-noise of the camera electronics.

The reasons for the above listed phenomena stem from, e.g.:

- Camera assembly inaccuracies.
- Impurities in or faults of the lenses and optical system aligning.
- Micro-faults and inaccuracies in the process of manufacture of CCD converter matrixes.
- Distortion of analogue signals in the camera and in the camera/video chart electronics.

Some of the technological faults may be eliminated. For example: different sensitivity of individual pixels at constant illumination may be corrected by establishing sensitivity mapping. In this report the problem of evaluation and elimination of noise in the vision signal has been dealt with.

3. Experimental work

An incentive for this research was the observation of the brightness level of the same pixels for some established conditions of image exposition. The fluctuations of brightness, which are present within one image or its sequence, stem from the non-stability of and interference in the image processing system. It is claimed that for a large number of specimens the arithmetic average of brightness for individual pixels is equal to the constant component. That also means that subsequent components of the brightness level in the series of recorded image frames may assume both positive and negative values.
To confirm the above formulated thesis, the optics of the camera was blended. Individual images (of a series of images) were registered and the level of blackness was measured. This technique allows for the control of constant elements of image distortions and to register the level of noise for individual pixels of the CCD converter matrix.
The result of the experiment confirmed the base assumptions. Fig. 2 shows the distribution of the number of points with the same brightness for a single exposition. It may be assumed as a Gauss

distribution with a slight asymmetry. The dominant component with the brightness 6 and 7, which is an average brightness for the whole image, may easily be singled out. It may also be assumed that there is a symmetry with respect to the central position of points with brightness 6 and 7 which is valid within limits given by the brightness of points 2 and 11.

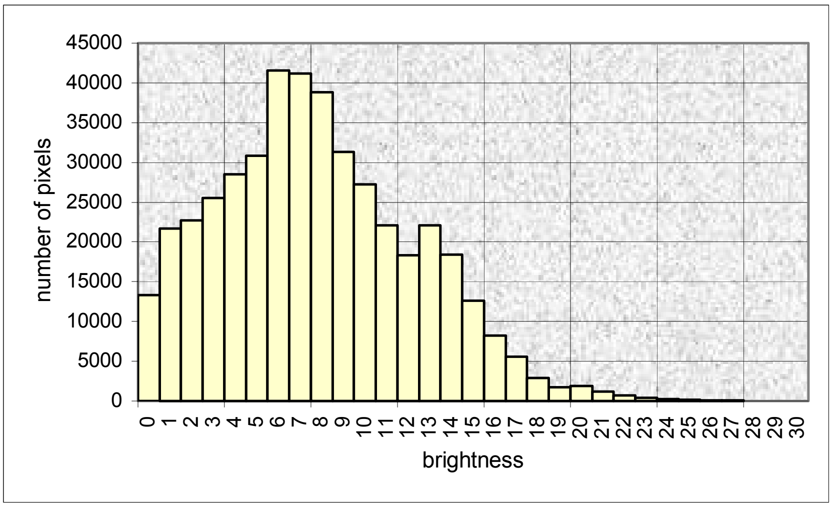

Fig. 2 Distribution of the number of pixels in term of pixel brightness on a bitmap made of one image.

The above pattern of the noise level distribution for a single image confirms the assumption that the same pattern is valid for the consecutive images. As a result, the level of noise for a selected pixel in the bitmap in the next images will be positive or negative with respect to the constant component of the noise. The constant component of the noise is identical for each consecutive image. As a result, the brightness of a given pixel, measured as the arithmetic average, will remain constant (at a certain fixed level) for a sufficiently large number of expositions.

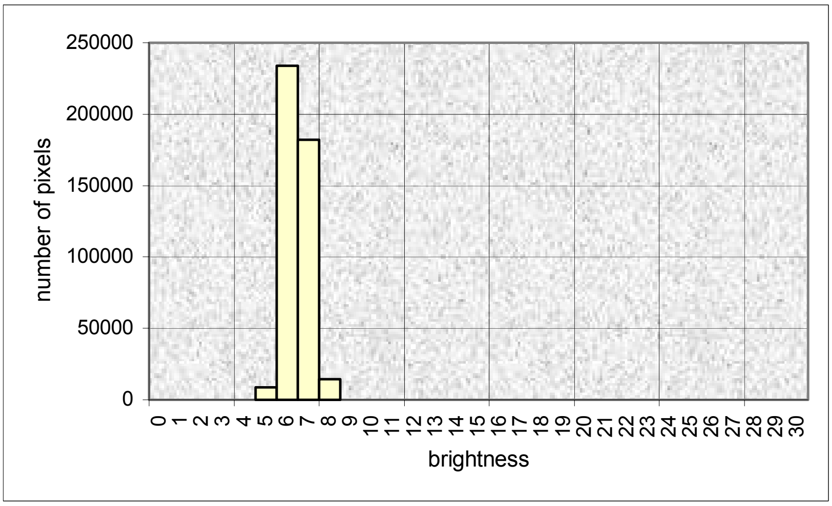

Fig. 3 Distribution of the number of pixels in terms of brightness in the bitmap made of 255 images.

Since the brightness value of a pixel in this process is approximately invariable and there is a possibility to include this information in an appropriate procedure, than this is the elimination of noise. The algorithm of noise elimination consists in the summation of brightness of each pixel in the image matrix (for the same exposition) and division of the results by the number of expositions. Fig. 3 presents the distribution of noise for a bitmap made of 255 images.

4. Final results

Calculations of the mean and standard deviations for 255 consecutive images obtained for the same expositions were made. The level of noise for individual pixels was measured and presented together with the mean and standard deviations, which is shown in Fig. 4. The values obtained (both in Fig. 4 and in the implemented algorithm of noise elimination) were determined based upon textbook formulas.

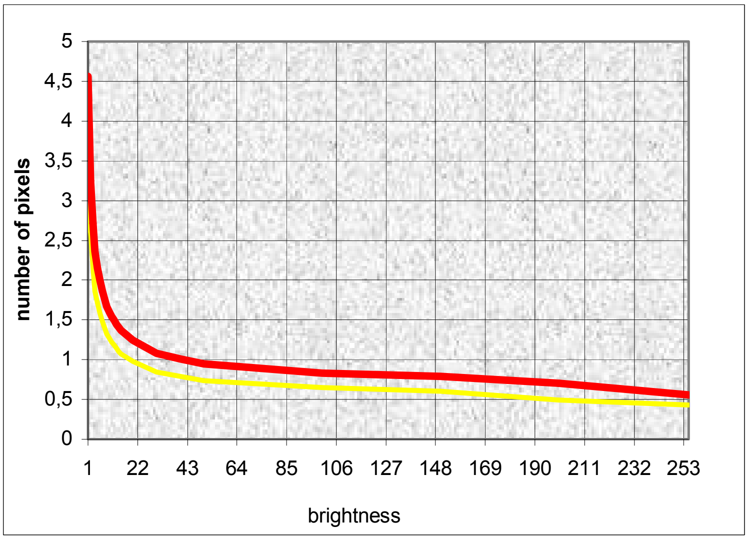

Fig. 4 Mean (yellow) and standard deviations (red) for the distribution of pixel brightness in a bitmap as a function of the number of component images

Based upon the analysis of the graph in Fig. 4 it is evident that with the proposed method the level of noise may be reduced 8 times (over 18 dB). This technique enhances the quality of images, which is beneficent to the comfort of operation and, consequently, to the level of accuracy in the evaluation of the geometry of the controlled objects.

References

[1] Dwořák R.: ”Meřeni ve Dvou Souřadnicich s Vypočetnim Programem M2D”, IX Konferencja N-T. Metrologia w Technikach Wytwarzania Maszyn. Częstochowa 2002. p.429-435.

[2] Main M., Baerl J.: ” Measurement of Profile by the Light-Cut Method”, VII Konferencja N-T, Kielce ’97, p.161-167.