

# CCD Camera Instrumental Background Estimation Algorithm

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**Abstract** – Noise can seriously affect quality of digital image. Its presence results with compromising a level of details. There are numerous methods of noise removal, however in general, they do not consider the specificity of CCD camera electronic components. In this paper method of CCD camera instrumental background removal is presented. Results of applying the algorithm to images obtained from image quantitative analysis system are presented and discussed. A brief description of the system is given.

**Keywords** – image enhancement, image noise, instrumental background, image quantitative analysis system.

## I. INTRODUCTION

CCD imaging sensors have become very popular nowadays. They have numerous advantages over photographic films so they are successfully used in many scientific applications for example in image quantitative analysis systems.

The images provided by CCD cameras are characterized by high quality, however they are not completely free from different types of distortions and artifacts.

All factors that produce non-uniform pixel output are called noise. Mostly, noise arises from electronic components of cameras [1][2]. There are three primary components of noise in CCD imaging systems: photon noise, readout noise and dark noise [1][2][5][6].

Photon noise is a fundamental feature of the quantum nature of light and is irreducible due to poissonian nature of counting photons. The second noise component – readout noise (known also as preamplifier noise) is generated by the on-chip output amplifier and cannot be completely removed from image. Finally dark noise (known also as dark current) is thermally generated charge that can be approximately measured and subtracted from the output image.

Noise can seriously damage digital image quality. Its presence compromise a level of details and in consequence makes important image information lost. In order to restore original image, noise removal process should be carried out.

There are numerous methods of noise removal [12][13][14]. In general they can be divided into two main groups: image filtration and image averaging. However, filtration affects with blurred appearance of an image what is

unacceptable in case of digital image analysis systems. Averaging - the second method of random noise removal is said to reduce noise level without compromising details. However, it involves at least several images of observed scene and in consequence cannot be used when view field changes rapidly. Moreover, in case of real-time processing all averaged images have to be stored in image processing system memory.

In general, custom methods of image reconstruction due to noise removal do not consider the specificity of CCD camera electronic components. All types of noise are treated in the same way. This affects with details compromising.

In the following part of this paper, method of CCD camera dark noise estimation and removal is proposed. The described method iteratively constructs successive approximations of image instrumental background.

Results of applying authors' algorithm to images obtained from computerized system for high temperature measurements of surface properties (wetting angle, surface tension) of liquid and solid in contact are presented and discussed. A brief description of the system is given.

## II. THE EXPERIMENTAL SETUP

The algorithm of CCD camera instrumental background elimination was tested on images acquired from "THERMO-WET" - computerized system for high temperature measurements of surface properties. Surface properties are calculated on the basis of drop shape analysis [8][9][10].

The system is property of Computer Engineering Department of Technical University of Lodz.

The apparatus of "THERMO-WET" consists of:

1. high-temperature (up to 1800°C) electric furnace with a protective atmosphere;
2. system for the precise temperature measurement and control;
3. technological gases supply system;
4. specimen insertion mechanism;
5. vision unit (CCD camera, image analysis and processing algorithms, infrared filters with the algorithm of their automatic changes);
6. computer for controlling all stages of the measurement process.

The general view of the measurement system has been presented on Figure 1. More detailed description of "THERMO-WET" can be found in [8][9][10].



Fig.1. The general view of "Thermo-Wet" system; 1- high-temperature electric furnace; 2- system for the precise temperature measurement and control; 3 - technological gases supply system; 4- specimen insertion mechanism; 5- vision unit; 6- computer;

The measurement process starts from placing specimen of investigated material inside the furnace. In order to do so insertion mechanism is used. The specimen under investigation is then heated to the temperature higher than the melting point. When it becomes drop, the "THERMO-WET" vision unit acquires images of the specimen and proceeds image segmentation. In the next step of the measurement process drop geometric parameters are determined (Fig.2) in order to calculate surface properties using Potter's equation [10][11].

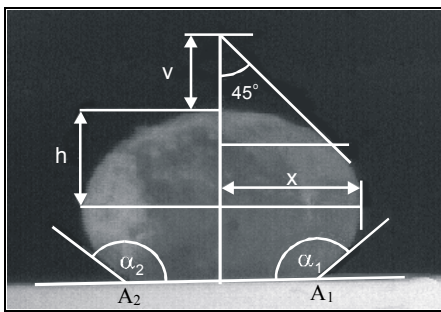


Fig.2. The specimen with important geometric parameters marked.

It should be pointed out that image quality is crucial for the measurement process. High quality of input images ensures better results of the segmentation process and in consequence more accurate determination of drop geometric parameters. Because of these facts, segmentation is preceded by image enhancement process that is to remove redundant information and extract information that is important for the measurement process. One of the steps of image enhancement is instrumental background elimination.

### III. INSTRUMENTAL BACKGROUND PRELIMINARIES

When no external light flux reaches the CCD sensors, the charge is only generated by thermal effects within the silicon lattice forming the CCD. Dark frame acquired when the CCD camera shutter is closed presents image of instrumental background. An example of dark frame is presented in figure 3a. The corresponding image after histogram stretching is also shown (Fig.3b). Presented images were acquired from 8-bit monochromatic Watec WAT 502A miniature CCD camera (which is a part of "THERMO-WET" vision system).

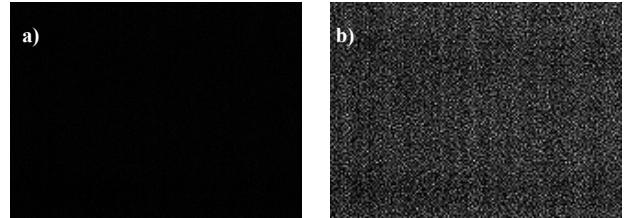


Fig.3. Example of dark frame; a) original image; b) an effect of histogram stretching.

Instrumental background is present in every digital image. It consists of two components i.e. bias voltage and dark current in accordance with equation (1).

$$L_{DF} = L_B + L_D \quad (1)$$

where:

- $L_{DF}$  - image of the instrumental background (dark frame);
- $L_B$  - image of bias voltage (zero frame);
- $L_D$  - image of dark current.

Dark current and bias voltage can seriously affect the quality of digital images. The problem occurs especially in case of low intensity images. Figure 4 illustrates the problem of image quality degradation due to instrumental background presence. Presented images show high-temperature specimens of aluminum (Fig. 4a) and copper (Fig. 4b). The specimen temperature is indicated on the figure. Images were acquired from "THERMO-WET" vision system using infrared filters. Instrumental background presence manifests itself by vertical lines of different intensity.

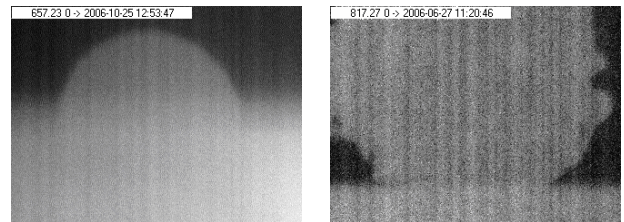


Fig. 4. Image quality degradation due to instrumental background presence.

Both, bias and dark current, should be removed from output image. The common methods of instrumental background components determination require adjustable exposition time [3][4][7]. However, this feature is only

available in astronomical cameras whereas in many scientific cameras exposition time is constant [1][2].

The author's idea of instrumental background determination is dedicated to CCD cameras with constant exposition time.

#### IV. GREY LEVEL DISTRIBUTION ANALYSIS

Histogram of dark frame from figure 3a is presented in figure 5 and table 1. Only significant grey levels (having values higher than 0) are presented.

Table 1. Significant grey levels percentage participation in the exemplary dark frame

Grey Level	Percentage participation [%]
0	3.788
1	18.289
2	29.434
3	27.720
4	13.944
5	4.907
6	1.625
7	0.257
8	0.034
9	0.001

Dark frames analysis led to the conclusion that pixels grey levels range is from 0 to 9 in range [0,255]. Zero pixels are in minority (less than 4%). Dominant intensities – about 60%, are concentrated with values 2 and 3. They are considered as result of bias presence. Remaining intensities are images of thermally generated charge i.e. dark current.

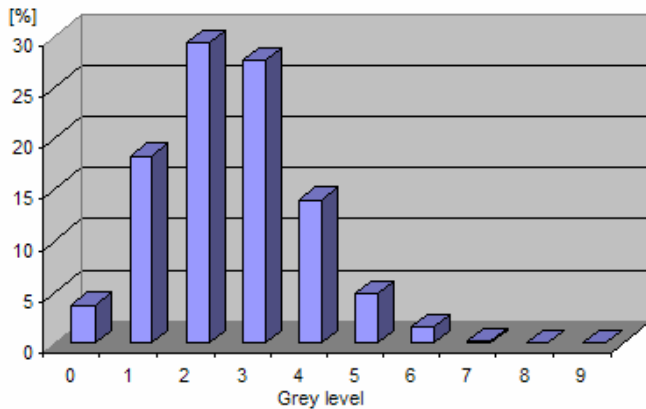


Fig.5. Significant intensities percentage participation in exemplary dark frame from figure 1.

Experiments proved that dark frame grey levels distribution can be considered constant for given CCD camera. It means that once constructed master dark frame can be simply subtracted from each out coming image.

The algorithm of master dark frame construction is presented in the following section of this paper. Algorithm extracts dominant constituents of instrumental background using successive iterations.

#### V. ALGORITHM DESCRIPTION

The presented algorithm uses a set of dark frames acquired from CCD camera. This set is subsequently used to construct image of the instrumental background.

Set of input dark frames is averaged in successive iterations in order to extract dominant components of the instrumental background. The average frame is then subtracted from each of the input frames in order to build input set for the next iteration. The process is repeated until there are no distortions in the average frame.

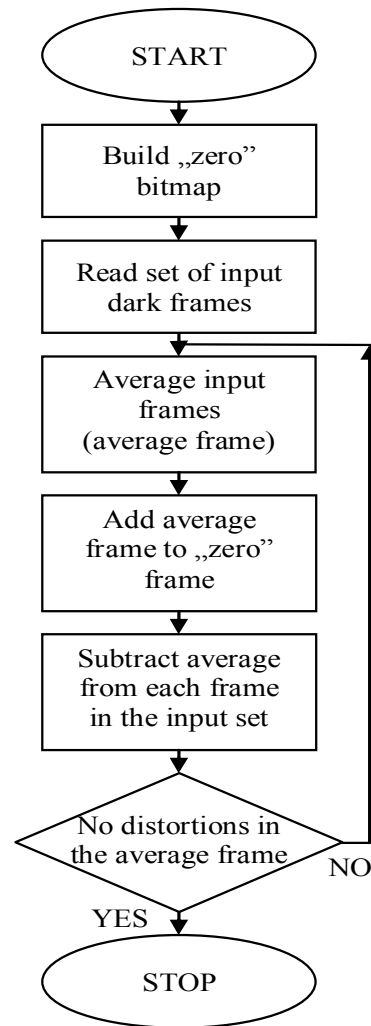


Fig.6. Flow diagram of the iterative dark current estimation algorithm.

Average frames from consecutive iterations are remembered. As it was mentioned before, they present images of instrumental background components. In order to



build master dark frame average frames from all iterations are summed up. The algorithm flow diagram is presented in figure 6.

## VI. RESULTS AND DISCUSSION

Image of instrumental background based upon 1800 dark frames acquired from Watec WAT 502A miniature CCD camera is shown in figure 7. For better results presentation effect of histogram stretching is presented.

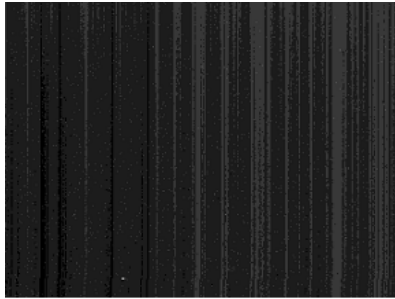


Fig.7. Image of instrumental background based upon 1800 dark frames acquired from Watec WAT 502A CCD camera.

Because dark current is irreducible, it is impossible to build master dark frame of infinite accuracy. However, accuracy of approximation depends on the number of iterations.

Table 2 presents influence of the number of iterations performed on the quality of instrumental background approximation. Consecutive images present results of master dark frame subtraction from exemplary dark frame.

First column indicates number of iterations used to construct master dark frame. Consecutive images present noise left in the exemplary dark frame after instrumental background subtraction. For better results presentation effects of histogram stretching is shown.

It can be easily seen that the noise level in the dark frame decreases with the number of iterations used to instrumental background image construction.

As it was mentioned before subtracting master dark frame from each image results with bias and dark current removal. Result of image enhancement due to master dark frame subtraction is presented in figure 8. The image presents specimen of copper at temperature 817<sup>0</sup>C.

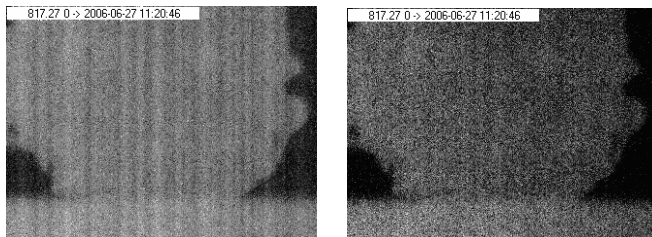


Fig. 8. Result of instrumental background elimination (contrast stretched).

It can be easily seen that subtracting master dark frame improves image quality. Vertical lines of different intensity were removed from the analyzed image.

Table 2. Properties of dark frames obtained in consecutive iterations.

	Exemplary frame	Frame properties
1		Avg. lightness: $\bar{L} = 2$ Contrast: $\sigma = 3$ No-zero pixels: 83,69%
2		Avg. lightness: $\bar{L} = 0$ Contrast: $\sigma = 1$ No-zero pixels: 41,61%
3		Avg. lightness: $\bar{L} = 0$ Contrast: $\sigma = 0$ No-zero pixels: 9,37%
4		Avg. lightness: $\bar{L} = 0$ Contrast: $\sigma = 0$ No-zero pixels: 9,23%

## VII. CONCLUSIONS

In this paper noise sources in CCD camera images were introduced. Particular attention was paid to thermally generated charge known as dark noise (or dark current). Method of dark noise level estimation for particular CCD camera was proposed. The method in successive iterations constructs consecutive approximations of instrumental background image. Final master dark frame can be then subtracted from each image acquired from CCD camera. The subtraction improves quality of the output image.

Results of applying authors' algorithm to images acquired from industrial quantitative analysis system were presented and discussed.

Proposed method can be particularly useful in case of low-light images. However, it can be successfully used in all CCD sensors applications as a part of image enhancement process.

## VIII. ACKNOWLEDGMENT

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