Digital X-ray image processing with using the adaptive histogram equalization and adaptive background correction

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Introduction

Microfocus X-ray is a combination of methods for receiving X-ray images using radiation sources with focal spots size less than 100 μm. Using these sources gives the opportunity to obtain images with a direct geometric image magnification 5-20 times. Today microfocus X-ray is widely used in medicine, industrial non-destructive testing and quality assessment of agricultural crops. [1,2,3].

In the list of cases, microfocus X-ray images could not be authentically analyzed because of insufficient quality of images. More often main disadvantages of microfocus X-ray images are irregular background, distorted brightness characteristics, the presence of noises. Therefore, the development of algorithms for digital processing of microfocus X-ray images is a relevant task.

Materials and Methods

In the paper, two algorithms of digital X-ray images processing are considered: the algorithm for correcting the uneven image background based on the subtraction of the distorting function and the algorithm for locally-adaptive histogram equalization.

Algorithm for correcting the image background

During the X-ray examination according to the scheme with the direct geometric magnification uneven image background arises, complicating visual analysis and subsequent digital image processing. A distorting function is introduced to eliminate irregular background of the image. It is considered that the receiver registers an image that can be represented as the sum of the image and the distorting function, which creates the uneven background. The distorting function in microfocus X-ray is usually described by a function of the form:

$$g(x,y) = C[(x - \frac{x_{max}}{2})^2 + \left(y - \frac{y_{max}}{2}\right)^2], \quad (1)$$

where C – is a constant, whose value depends on the microfocus X-ray apparatus mode and the shooting conditions, x_{max} and y_{max} – is the vertical and horizontal size of the image respectively.

This form of distorting function follows from shooting peculiarities with image enlarging, as X-ray radiation intensity decreases proportionally to the square of the distance.



Figure 1: Image for the analysis

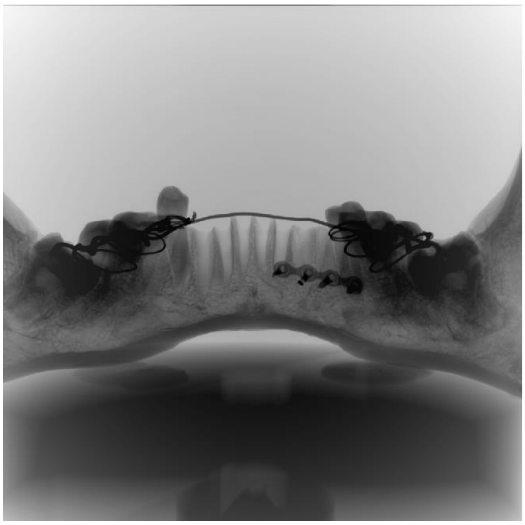


Figure 2: The result of image background correction

For every single profile, its minimum and maximum are determined and the difference between them is found. The constant C is determined by the expression (2) as the medium difference between minimum and maximum of the profiles.

$$C = \frac{\sum_k^N (a_{k\,max} - a_{k\,min})}{N}, \quad (2)$$

where N – the number of profiles, $a_{k\,max}$ and $a_{k\,min}$ – respectively maximum and minimum brightness values. In case of the big difference between profiles minimums and maximums the number of the analysed profiles should be increased to get the correct constant.

On figure 3 profile built along the upper edge of the image is presented.

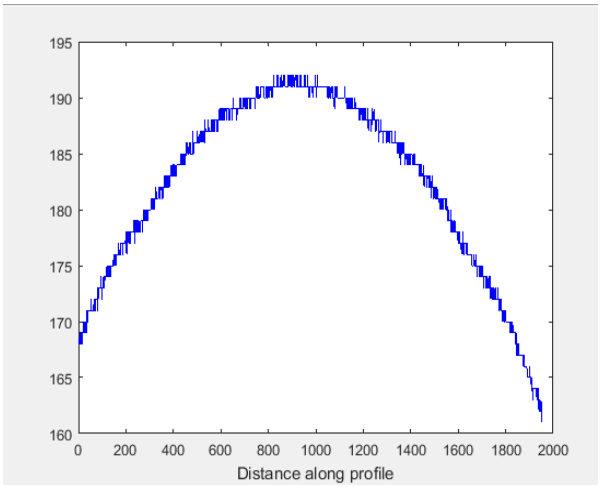


Figure3: Profile of the upper edge of the image

The resulting image *f(x,y)* is obtained by the way of subtraction *g(x,y)* from image registered by the receiver:

$$f(x,y) = h(x,y) - g(x,y) \qquad (3)$$

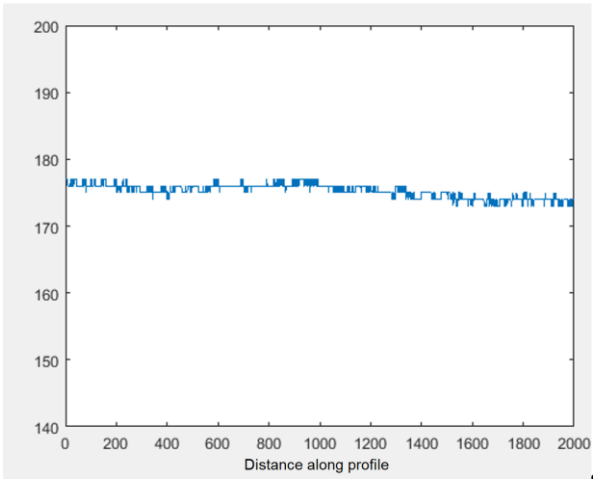


Figure4: Profile of the upper edge of the image after correction

On the figure 4 profile built along the upper edge of the image after the correction of the tone is presented. As it's shown in the figure 3 profile of the image is aligned, uneven background illumination is removed. After image background correction, it's much more convenient for automatic analysis. Visual analysis also becomes easier. So, for teeth image selection on the image primitive threshold transformation can be used, while in a case of uneven background it is ineffective.

The algorithm of local-adaptive equalization of the histogram

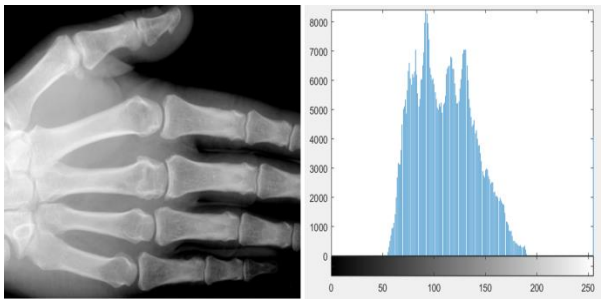


Figure5: The original image and its histogram

The method of the local-adaptive histogram equalization can be also used for the image's contrast improving.

Histogram of the image is a function defined as:

$$h(r_k) = n_k, \qquad (4)$$

where r_k – *k*- is a level of brightness on the image, n_k– number of pixels, belonging to this level of brightness. If the image has a low contrast, this means that the histogram values are concentrated in a certain region of the brightness range [5]. For improving contrast it's necessary for non-zero levels of the histogram to overlap the bigger part of the range of brightness. Equalization of the histogram is a transformation that can be described by the formula:

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n}, \qquad (5)$$

where s_k – k-level of the brightness of the processed image, n – the common number of pixels on the image, n_j– number of pixels that have brightness r_k.

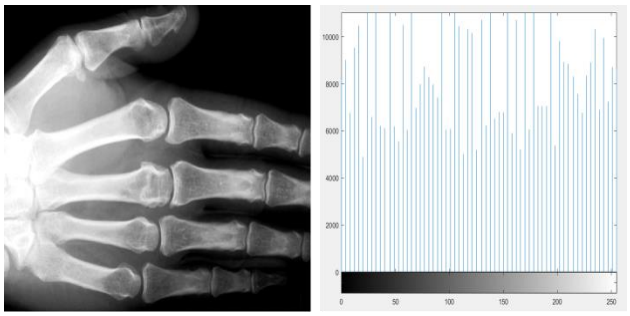


Figure6: The image and its histogram after using the method of histograms' equalization

This method allows you to significantly increase the contrast of X-ray microfocus images without the operator's participation. However, the method of the histogram equalizing does not lead to the desired result if the image has an uneven background or if the image has a wide histogram.

To overcome listed limitations method of local-adaptive histogram's equalization is applied: at first in the method of local-adaptive histogram's equalization the image is splitted into a number of non-crossing areas (usually from

16 to 128) and then every single area is subjected to the histogram's equalization. On the next step, all the areas are combined into a single image with the bilinear interpolation. For removing artificial borders, which appear in the combining areas, the interpolation is used. In this way, there is a local increase in the contrast of the main image details.

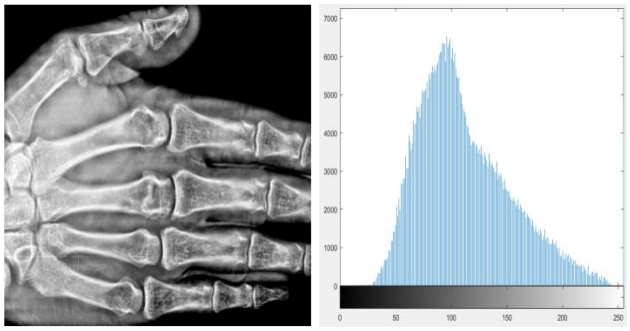


Figure7: Image and its histogram after using the method of the local-adaptive equalization of the histogram

Results and discussion

To check the quality of method of the background correction a sample of 100 medical microfocus X-ray images obtained using different radiation receivers was used.

As the result of the developed method backgrounds of the 73% of the images were fully leveled (pixel brightness values difference between the edges and the center has become less than 5 points), for 27% of the images pixel brightness values difference between the edges and the center has become less than 10 points.

Every single wrong case of the background correction was considered in details. In all the cases error was caused by the fact that objects in the image occupied more than 80% of the length of the profile, so there wasn't enough information to determine the background.

To check the quality of method of the background correction a sample of 50 medical microfocus X-ray images was used. As the result of the application of the method of histogram's adaptive equalization to all images from the sample for 80% of the images, a notable contrast increase was fixed. It also became possible to distinguish the details of tissues and bones. If the traditional method of histogram equalization is applied to the same images, significant improvement in contrast, without deterioration of contrast in other areas of the image, was achieved only in 40% of cases.

Conclusions

As the result the algorithm for image background correction and algorithm of the local-adaptive histogram equalization was developed.

On the samples of microfocus X-ray images, investigations of developed methods were done. Both of the methods gave satisfactory results.

Also, it was determined that while doing the local-adaptive equalization of the histogram, contrast image of both soft and osseous tissues can be reached on the same shot.

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The advantages of background correction of microfocus X-ray images are presented.