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S. V. Balovsyak, O. V. Derevyanchuk, H. O. Kravchenko, O. P. Kroitor, V. V. Tomash, "Computer system for increasing the local contrast of railway transport images," Proc. SPIE 12126, Fifteenth International Conference on Correlation Optics, 121261E (20 December 2021); doi: 10.1117/12.2615761

Event: Fifteenth International Conference on Correlation Optics, 2021, Chernivtsi, Ukraine

Computer system for increasing the local contrast of railway transport images

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ABSTRACT

This article describes a computer system for increasing the local contrast of railway images obtained with digital video cameras. The local contrast of the images increases within the rectangular windows, for each of which the minimum and maximum brightness values are determined. Based on such extreme brightness values, the lower and upper envelope brightness of the image are calculated. By smoothing of the envelopes the artefacts that appear in the image after increasing the local contrast based on its envelopes are significantly reduced. The images are read to the control computer from USB video cameras. The software implementation of image processing is created in Python.

Keywords: digital image processing, local contrast, digital video camera.

1. INTRODUCTION

Today there is a need to develop automatic tools for analysing the condition of rolling stock on railway transport, namely the condition of trains and cars. In many cases, information about trains and cars is obtained using video cameras in the form of digital images[1-2]. Common tasks for processing such images are the selection of content areas (segments) and calculation of their parameters, as well as the recognition of objects in images[2-3]. For example, inscriptions, license plates, windows, headlights, homogeneous sections of walls, wheels, etc. are distinguished as segments. However, real images of trains and cars are characterized by a certain level of noise, inhomogeneous background and contrast. Such image defects usually occur due to insufficient or inhomogeneous lighting of objects and significantly reduce the accuracy of further image processing. In this case, the experimental conditions for obtaining images in most cases are difficult or impossible to change.

Therefore, in order to increase the accuracy of segmentation and further image processing, a computer system has been developed in which the original images are obtained using video cameras. Image processing is to reduce their noise level by filtering, as well as to remove inhomogeneous background and increase contrast. Existing methods of increasing local contrast, which use window image processing, lead to the appearance of artefacts in the images[1-2]. Therefore, in the developed system as a result of window image processing, its lower and upper envelope brightness are first calculated[4], and then their smoothing is performed. Due to this smoothing, the distortion of images that occur when increasing their local contrast was reduced. In addition, by subtracting the lower envelope, it is possible to remove the inhomogeneous background of the image. Reading images to the control computer is performed from USB video cameras as separate frames of the video stream. The software for image processing is developed in Python.

2. MATHEMATICAL MODEL OF INCREASING LOCAL CONTRAST OF IMAGES

The digital image obtained from the video camera is recorded in a rectangular matrix $f_{RGB} = f_{RGB}\,(i, k, c)$, where $i = 0, ..., M\text{-}1$; $k = 0, ..., N\text{-}1$; $c = 0, ..., 2$; M is the height of the image (in pixels), N is the width of the image (in pixels), c is the colour channel number (red, green, blue). Further image processing is performed in shades of gray as a matrix $f = f\,(i, k)$, where $i = 0, ..., M\text{-}1$; $k = 0, ..., N\text{-}1$. To do this, the colour image f_{RGB} is converted to an image in shades of gray f by averaging the values of its colour channels.

Next, the dimensions of the local windows w of the image are determined, namely their height M_w and width N_w. By default, the windows w are square, i.e. $M_w = N_w$. When processing locally, windows w are formed for each pixel of the image f, while the pixel is placed in the centre of the window at a distance of $M_{w2} = [M_w / 2]$ from its upper edge and at a distance of $N_{w2} = [N_w / 2]$ from its left edge.

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Fifteenth International Conference on Correlation Optics, edited
by Oleg V. Angelsky, Proc. of SPIE Vol. 12126, 121261E
© 2021 SPIE · 0277-786X · doi: 10.1117/12.2615761

Within each window w, the minimum and maximum brightness values are calculated. The obtained values of local minima are written in the rectangular matrix of the lower envelope $f_{min1} = f_{min1}(i, k)$, where $i = 0, ..., M$-1; $k = 0, ..., N$-1. The obtained values of local maxima are written in the rectangular matrix of the upper envelope $f_{max1} = f_{max1}(i, k)$, where $i = 0, ..., M$-1; $k = 0, ..., N$-1.

Based on the envelopes (f_{min1}, f_{max1}) and the initial image f, the result image f_C with increased local contrast and removed inhomogeneous background is calculated by the formula

$$f_C(i,k) = \frac{f(i,k) - f_{\min 1}(i,k)}{f_{\max 1}(i,k) - f_{\min 1}(i,k)} = \left(f(i,k) - f_{\min 1}(i,k)\right) \cdot k_C(i,k), \quad (1)$$

where $i = 0,..., M-1$; $k = 0,..., N-1$; $k_C(i, k) = 1/(f_{max1}(i, k) - f_{min1}(i, k))$ – local contrast coefficients.

In order to prevent the appearance of artefacts (e.g., parasitic contours) on the restored f_C images, the maximum values of the local contrast ratios k_C are set to the limit k_{CMax} (e.g., $k_{CMax} = 5$). To ensure high visual quality of f_C images, the lower f_{min1} and upper f_{max1} envelopes are also filtered by convolving them with the kernel w_G of the Gaussian filter (with the size $M_{wG} \times N_{wG}$ elements) according to the formulas:

$$f_{\min 1c}(i,k) = \sum_{m=0}^{M_{wG}-1} \sum_{n=0}^{N_{wG}-1} f_{\min 1}(i - m + m_c, k - n + m_c) \cdot w_G(m,n), \quad (2)$$

$$f_{\max 1c}(i,k) = \sum_{m=0}^{M_{wG}-1} \sum_{n=0}^{N_{wG}-1} f_{\max 1}(i - m + m_c, k - n + m_c) \cdot w_G(m,n), \quad (3)$$

where $f_{min1c} = f_{min1}(i, k)$ – filtered lower envelope; $i = 0, ..., M$-1; $k = 0, ..., N$-1;
$f_{max1c} = f_{max1}(i, k)$ – filtered upper envelope; $i = 0, ..., M$-1; $k = 0, ..., N$-1;
$m_c = (M_{wG2} + 1)$ – the centre of the kernel w_G of the filter in height;
$n_c = (N_{wG2} + 1)$ – the centre of the kernel w_G of the filter in width;
M_{wG2}, N_{wG2} – whole parts of half the size of the kernel w_G of the Gaussian filter.

The kernel w_G of the filter is described by a two-dimensional Gaussian function with standard deviation σ_{wG}. The sum of the elements of the kernel w_G of the Gaussian filter is equal to 1.

3. PRINCIPLES OF WINDOW IMAGE PROCESSING

Before window processing on the basis of the initial image f (fig. 1) the extended image f_e (fig. 2) is calculated. A symmetric image extension is used in this work, in which bands with width M_{w2} are added to the left and right in the image f_e, and bands with width N_{w2} are added at the top and bottom. The brightness of the bands is calculated as the brightness of the pixels of the image f, symmetrical about the boundary (the boundary of the image f on f_e is marked by a red dashed line around the perimeter of the image f_e in Fig. 2). Subsequently, the window processing of the extended image f_e was performed, in which the centres of the windows w are shifted by the value of M_{w2} from the edge of the image in height and by the value of N_{w2} in width.

Fig. 1 – Initial image f

Fig. 2 – Extended image f_e, obtained on the basis of image f (Fig. 1); window w with element sizes $M_w \times N_w$ ($M_w = N_w = 64$) is highlighted by a dashed line in the upper left corner of the image

Due to this, the windows w do not go beyond the image and within each window correctly calculate its minimum and maximum value with high speed (because do not need to check the conditions of the window outside the image).

4. HARDWARE AND SOFTWARE IMPLEMENTATION OF IMAGE CONTRAST INCREASING

A block diagram of a computer system for increasing the local contrast of images has been developed (Fig. 3), which uses a video camera as a source of initial images f_0. The USB video camera "Logitech C270" was used in this work. The photosensitive matrix of camera is a type of CMON (complementary metal-oxide semiconductor) which has a resolution of 1280 × 720 pixels. In the test mode it is possible to read the initial images from the image files.

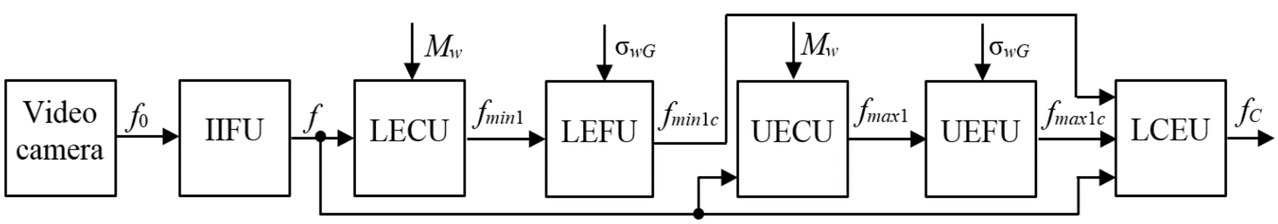


Fig. 3 – Block diagram of a computer system for increasing the local contrast of images

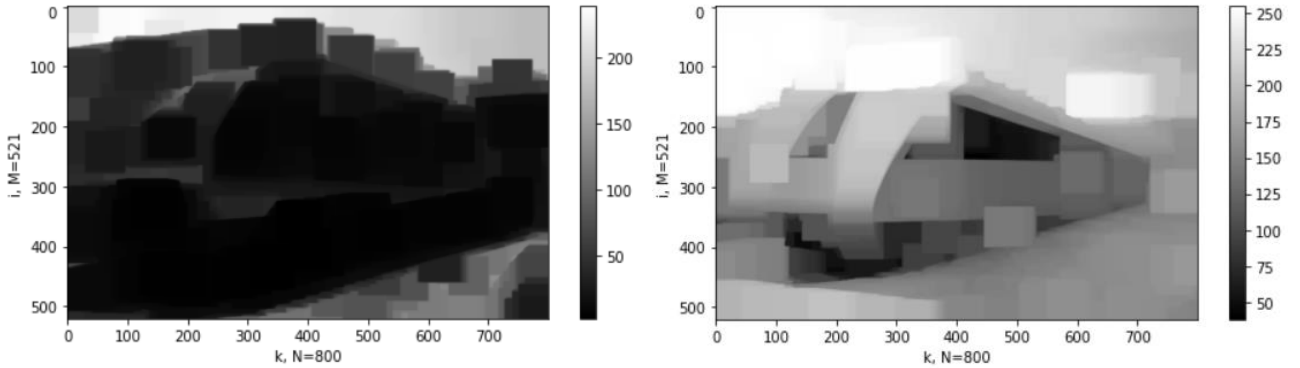
According to the proposed block diagram (Fig. 3) in the initial image filtering unit (IIFU) the low-frequency filtering of image f_0 is performed, resulting is the calculation of the image f with low noise. Filtration is performed by a median filter or by a bilateral filter[5]. Bilateral filtering has a lower speed (compared to the median), but provides better preservation of the clarity of the contours. In the case of filtering images of objects oriented in a certain direction, oriented image filtering is applied[6].

In the lower envelope calculation unit (LECU), the values of the lower envelope f_{min1} (Fig. 4a) are calculated as the minimum values within the local windows.

The lower envelope filtration unit (LEFU) is designed to obtain a smoothed lower envelope f_{min1c} (Fig. 5a) according to formula (2).

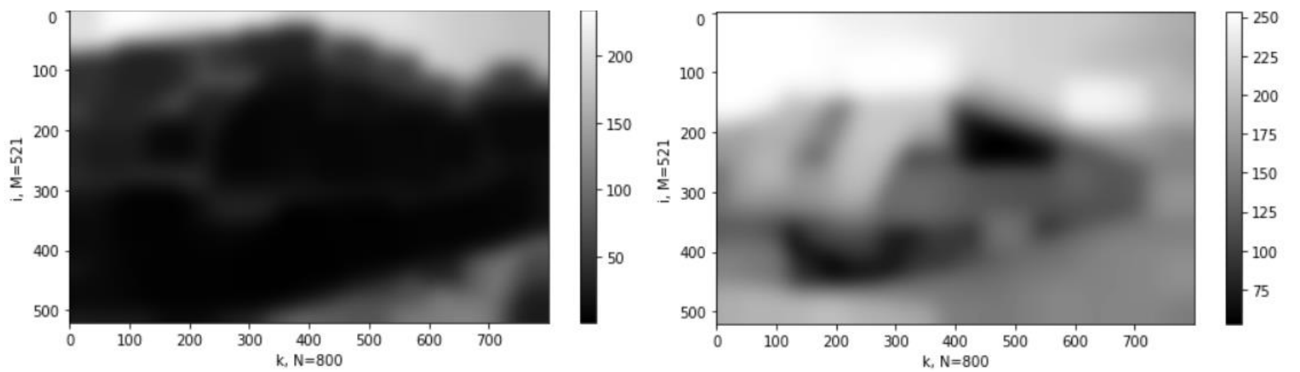
In the upper envelope calculation unit (UECU), the values of the upper envelope f_{max1} (Fig. 4b) are calculated as the maximum values within the local windows.

The upper envelope filtration unit (UEFU) is designed to obtain a smoothed upper envelope f_{max1c} (Fig. 5b) according to formula (3). It is established that when convolving the lower and upper envelopes, the best visual quality of the image-results is obtained if the standard deviation of the kernel of the Gaussian filter $\sigma_{wG} = M_w / 4$.



a) b)

Fig. 4 – The values of the lower f_{min1} (a) and upper f_{max1} (b) enveloping the brightness of the image f (Fig. 1)



a) b)

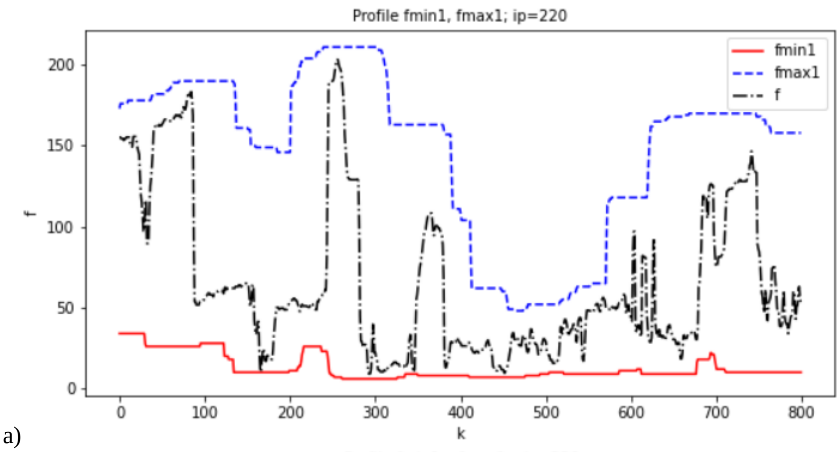
Fig. 5 – The values of the filtered lower f_{min1c} (a) and upper f_{max1c} (b) enveloping the brightness of the image f (Fig. 1); the standard deviation of the kernel of the Gaussian filter $\sigma_{wG} = 16$

In the local contrast enhancement unit (LCEU), the inhomogeneous background is removed and the local contrast of the images is increased according to formula (1). When changing the local contrast, only increasing the brightness of the pixels is acceptable (this preserves the high brightness for bright areas, such as the sky). The brightness of insufficiently dark areas is reduced by subtracting the background.

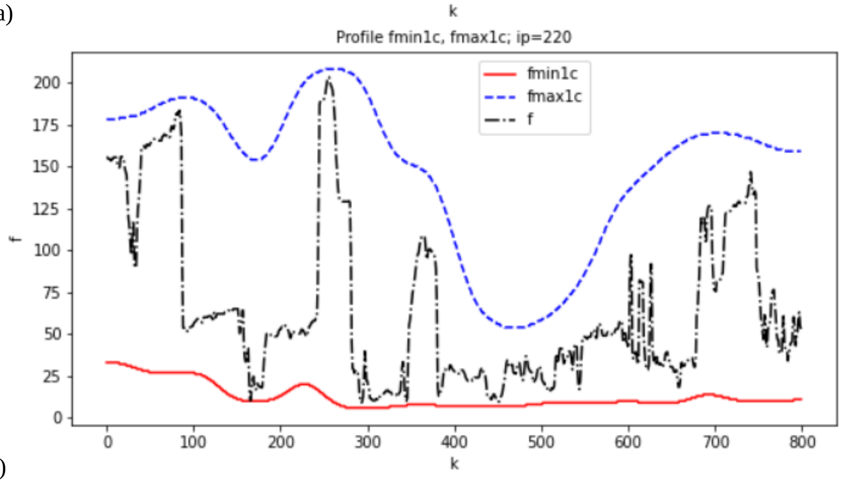
The above-described blocks of the computer system for increasing the local contrast of images (except for the video camera) (Fig. 3) are implemented as a software in Python, which is performed by means of a personal computer. Since such blocks mainly perform matrix convolution operations, such blocks can be implemented hardware using an FPGA (Field-Programmable Gate Array)[7].

The brightness of the initial image f is in the range between the lower and upper envelopes (Fig. 6), and the brightness of the resulting image f_C (Fig. 7) expands to the maximum possible range.

A significant increase in the local contrast of images is especially noticeable on image profiles and when comparing fragments of the original f and processed f_C images (Fig. 8).



a)



b)

Fig. 6 – Profiles of the lower and upper envelope, as well as the initial image *f* (Fig. 1) for the pixel line i = 220: a) profiles of the lower f_{min1} and upper f_{max1} envelopes; b) profiles of filtered lower f_{min1c} and upper f_{max1c} envelopes

Fig. 7 – The image fC with the removed inhomogeneous background and the increased local contrast received on the basis of the initial image *f* (fig. 1); window dimensions $M_w = N_w = 64$ (with filtration of envelopes)

As a result of processing of test images by means of the developed system the image with high local contrast was received, but without appreciable artefacts.

Fig. 8 – Fragments of the initial image f (Fig. 1) and the image f_C (Fig. 7) with high local contrast

When processing color images, the values of the pixels of the color image g_{RGB} (Fig. 9) with high contrast are calculated by the formula

$$g_{RGB}(i,k,c) = \frac{f_C(i,k) \cdot f_{RGB}(i,k,c)}{f(i,k)}, \tag{4}$$

where $i = 0,..., M\text{-}1$; k = 0,..., $N\text{-}1$; $c = 0, ..., 2$; f_{RGB} – initial color image.

a) 

Fig. 9 – Color initial image f_{RGB} (a) and color image g_{RGB} (b) with increased local contrast

b)

5. CONCLUSION

A computer system has been developed to increase the local contrast of railway transport images obtained by USB video cameras. The local contrast of the images is enhanced by their window processing using the lower and upper envelopes of the image. Before window processing, a symmetrical image extension is performed, which provides high-speed calculation of local extrema. Due to the filtering of the envelopes, the artifacts that appear in the image after increasing the local contrast are significantly reduced. As a result of processing of test images by means of the developed system the images with high visual quality are received that considerably simplifies their further processing.

REFERENCES

[1] Russ J. C. [The Image Processing Handbook], Abingdon-on-Thames, UK: Taylor and Francis Group, 838 (2011)

[2] Bovik A.L. [The Essential Guide to Image Processing], Amsterdam, The Netherlands: Elsevier Inc., 853 (2009).

[3] Berezsky O., Zarichnyi M. and Pitsun O., “Development of a metric and the methods for quantitative estimation of the segmentation of biomedical images”, Eastern-European Journal of Enterprise Technologies. Vol. 6/4 (90), 4-11 (2017).

[4] Balovsyak S.V., Fodchuk I.M., Solovay Yu.M., Lutsyk Ia.V., “Multilevel method of local contrast increase and images heterogeneous background removal”, Cybernetics and Computer Engineering. Vol. 182, 15-26 (2015).

[5] Balovsyak S., Borcha M., Gregus ml. M., Odaiska Kh. and Serpak N., “Automatic Processing of Digital X-ray Medical Images by Bilateral Filtration Method”, IntelITSIS 2021: 2nd International Workshop on Intelligent Information Technologies and Systems of Information Security, March 24-26, 2021. Khmelnytskyi, Ukraine, CEUR Workshop Proceedings. Vol. 2853, 280-294 (2021).

[6] Balovsyak S.V., Derevyanchuk O.V., Fodchuk I.M., Kroitor O.P., Odaiska Kh.S., Pshenychnyi O.O., Kotyra A. and Abisheva A., “Adaptive oriented filtration of digital images in the spatial domain”, Proc. SPIE 11176, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments. 111761A (6 November 2019), 111761A1-111761A6 (2019).

[7] Kabbai L., Sghaier A., Douik A. and Machhout M., "FPGA implementation of filtered image using 2D Gaussian filter", International Journal of Computer Science and Applications (IJACSA), Vol. 7 (2), 514-520 (2016).