UDC 355.233.1.005

K.S. Smelyakov, E.M. Drob

Ivan Kozhedub Kharkov Air Force University, Kharkov

ADAPTIVE MODEL FOR ENHANCEMENT OF DIGITAL IMAGE SHARPNESS

It is proposed an adaptive model and method for sharpness enhancement of digital image objects which allow to decrease significantly the level of manifestation of the basic shortcomings pertaining to up-to-date sharpness filters and thus to increase effectively the sharpness of digital images.

Keywords: *digital image, effectiveness, adaptation, model, method, sharpness filter.*

Introduction

In many applications concerned with analysis of digital images the objects of interest may have a low contrast level relative to a background that surrounds them. This gives rise to a problem of non-detection of low contrast objects being presented at the image [1 – 4].

In such circumstances it becomes impossible to use time-effectual and precise automatic machine vision systems for detection and analysis of low contrast images [5]. For elimination of this problem, at a stage of pre-processing the methods are used which increase an image sharpening in order to make the object bounds, lines and small details more contrast, as well as to improve a perception of objects that were defocused for various reasons [2, 5].

At the same time, the models being widely used now for increasing the image sharpness are characterized by a series of substantial disadvantages [1, 6, 7].

The principal of them are stipulated by application of such models which presume increase the image pixel sharpness proportionally to their contrast level without constraints.

Thus for increasing a digital image sharpness, at present the following generalized model is usually used

$$f'(x,y) = f(x,y) + g(x,y), \qquad (1)$$

where $f(x,y)$ – is the source value of brightness, $f'(x,y)$ – a new value of brightness, and $g(x,y)$ – the increment of brightness for pixel $d(x,y)$. For example, a generalized Laplacian model proposed for improving an image is given by

$$f'(x,y) = \begin{cases} f(x,y) - \nabla^2 f(x,y), & \text{if } w(0,0) < 0, \\ f(x,y) + \nabla^2 f(x,y), & \text{if } w(0,0) \ge 0, \end{cases} \qquad (2)$$

where $\nabla^2 f(x,y)$ – is the value of gradient that reflects the level of drop of brightness in a vicinity of the pixel $d(x,y)$, and $w(0,0)$ – is the is the value of central coefficient of the Laplacian mask [1]. Making use of such models results in that, that after raising of sharpness the brightness f' of image pixels takes the value on the interval $[a', b']$ being significantly more wide than the standard brightness interval $[0, 255]$.

In this situation it is required to normalize the values of brightness f' so that the normalized values $\|f'\|$ belong to the standard brightness interval $[0, 255]$.

Meanwhile, due to the fact that contrast object bound pixel sharpness increases much faster than the sharpness of the remaining image pixels, after normalization the informative brightness diapason of the image will be compressed inadmissibly.

Quite often a broad informative brightness diapason pertaining to an overwhelming majority of object and background pixels is compressed by an order of magnitude. In this situation, after normalization only the bounds of contrast objects will be clearly seen at the image, with a pronounced bound halo which, within the areas of local bound irregularity, will be presented by noise salt and pepper [1, 3].

Besides, increase of sharpness is frequently accompanied by asymmetrical widening of bounds of brightness interval $[0, 255]$. In this situation a normalization leads to disproportional compression of informative brightness interval of the image; apart from other shortages, it is manifested in unnatural defecation or darkening of the image [7].

Therefore, at present a topical question presents development of a model that would allow us to efficiently increase the sharpness of digital image, but without compression of its informative brightness interval.

Meanwhile, since the sharpness increase methods are instable to noisiness (such methods increase an image noise), we suppose that the noise of image $f(x,y)$ is preliminary smoothed [1, 2, 7].

1. Sharpness increase model

For solving of the stated problem it is proposed the following basic sharpness increase model

$$f' = \begin{cases} \lfloor f + sn \cdot \Delta f \rfloor, & \text{if } 0 \le \lfloor f + sn \cdot \Delta f \rfloor \le 255, \\ 0, & \text{if } \lfloor f + sn \cdot \Delta f \rfloor < 0, \\ 255, & \text{if } \lfloor f + sn \cdot \Delta f \rfloor > 255, \end{cases} \qquad (3)$$

where $f = f(x,y)$ – is the source value, $f' = f'(x,y)$ – new value of pixel brightness, Δf – the absolute value of brightness increment, sn – signum function, and $\lfloor \cdot \rfloor$ – the round-up operation.

Such model is proposed for the new brightness values f' of image pixels to fit the standard brightness diapason $[0, 255]$ without normalization of brightness f' and worsening of image photorealism.

The signum function sn in model (3) serves for adequate increasing (decreasing) of the brightness level of bright (dark) pixel over a dark (bright) background, and is defined as follows

$$sn = \begin{cases} u_0/|u_0|, & \text{if } |u_0| \ge |u_n|, \\ u_n/|u_n|, & \text{else,} \end{cases} \quad c \ne 0, \qquad (4)$$

where the contrast values u and c are estimated in the following way.

In accordance with the differential rule for estimating a pixel contrast [8], for an ε-vicinity $O_\varepsilon(x,y)$ of pixel $d(x,y)$ obtain a contrast spectrum and order it by augmentation

$$\{u_i\}_{i=0,\dots,n}, \; u_0 \le u_1 \le \dots \le u_n, \qquad (5)$$

$$c = \max\{|u_0|, |u_n|\}, \qquad (6)$$

$$u_i = f - f_i, \; f(x,y) \ne f_i, \qquad (7)$$

where f (c) – is the brightness (contrast) of image pixel $d(x,y)$, and f_i – are the values of brightness of pixels of its ε-vicinity which are specified by the position of contrasting operator mask with the centre in (x,y).

The absolute value Δf of increment of brightness f of pixel in the model (3) is defined as follows

$$\Delta f = y(\arg(c); k, p) = k \cdot (\arg(c)/255)^p \cdot \arg(c), \qquad (8)$$

where k – is an integral coefficient, and p – the order of power of sharpness gain function.

At this, the argument $\arg(c)$ in model (8) is defined this way

$$\arg(c) = \begin{cases} c, & \text{if } c < T_c, \\ T_c - (c - T_c) \cdot \dfrac{T_c}{255 - T_c}, & \text{else,} \end{cases} \qquad (9)$$

where c – is the pixel contrast found by the rule (6), and T_c – is the threshold that defines such a value of contrast $c^* = T_c$ after which the increment of absolute value Δf of brightness f would decrease only (Fig. 1).

Making use of the proposed model for estimating the absolute value Δf of increment of pixel brightness f for model (3) enables to efficiently increase an image sharpness at the expense of adjustment of parameters (k, p, T_c) of models (8) and (9) onto peculiarities of application problem.

Varying the integral coefficient k allows to regulate a general level of image contrast gain by specifying the balance between the sharpness and degree of manifestation of bound halo effect.

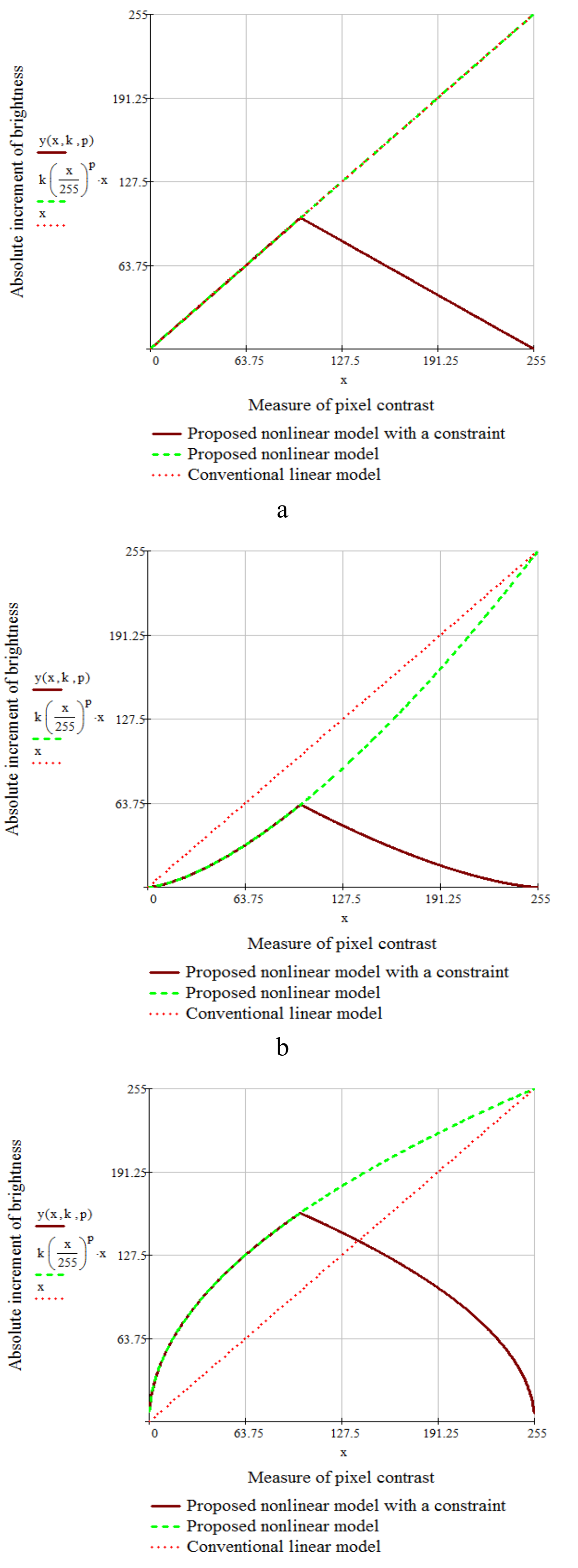

Fig. 1. Models of forming of absolute increment of brightness, where (at $k = 1$ and $T_c = 100$) the power p takes the values $p = 0$ (a), $p = 0.5$ (b) и $p = -0.5$ (c)

At this, the peculiarity of model (8) is that it enables to adjust the power p of sharpness gain function with the aim to adapt this model to the requirements of application problem:

a) if a proportional sharpness increase is required, the power p is set up to zero, ($p = 0$), and the model (8) takes a conventional linear form (Fig. 1.a);

b) if the contrast drops are required to be increased intentionally, while, at the same time, non-contrast brightness drops are not to be amplified, the power p is set up to a value exceeding zero, ($p > 0$), as it is shown in Fig. 1.b;

c) if it is required to amplify the non-contrast drops significantly, and, concurrently, to amplify the contrast brightness drops but insignificantly, the power p is set up to a value being less zero, ($p < 0$), as it is shown in Fig. 1.c.

Making use of the threshold T_c for finding the argument $\arg(c)$ of function $\Delta f = y(\arg(c); k, p)$ is required for not augmenting of significant brightness drops with the aim to ban an excessive increase of sharpness and to minimize the halo and noise effects of salt-and-pepper that arise at the object bounds.

2. Sharpness increase method

For a practical implication of the described model (3) it is proposed a sharpness increase method (is-method), which is defined by the following basic steps. Suppose that the radius of the mask intended for estimating of pixel contrast is defined relative to (7), and the parameters (k, p, T_c) of models (8) and (9) are given as well.

Step 1. Forming of table-function for absolute increment of brightness. As far as the contrast c being estimated relative to (6) takes the values on the set of non-negative integers on the interval $[0,...,255]$, with the use of model (8) obtain a table-function $\Delta f = \Delta f(c)$ for the values of absolute increment of brightness, where $c = 0,...,255$.

Step 2. Increase of sharpness. While scanning the image, for each its pixel:

a) find the minimal u_0 and maximal u_n pixel contrast within its vicinity;

b) with respect to expressions (4) and (6) find the contrast value c and the sign sn;

c) with the use of the defined table-function $\Delta f = \Delta f(c)$ and the values of parameters c and sn, find the new brightness f' by the rule (3).

Step 3. End.

Conclusions

The proposed sharpness increase model (3) allows us to exclude the necessity of normalization and compression of image informative brightness interval, and thus facilitates parametric adaptation to the requirements of application problems.

Due to the use of table-function $\Delta f = \Delta f(c)$, the time requirements of the proposed sharpness increase method by an order of magnitude are the same as for analogues. As a result, due to the use of above-proposed model (3), the described is-method provides effective and adequate increase of sharpness of digital images in a sense of excluding the disadvantages pertaining to its up-to-date widely used analogues.

Meanwhile, for minimizing the effects of noise and bound halo amplification, it is expedient to apply the proposed sharpness increase method just to the preliminary detected object and line bound pixels [8].

References

1. Rafael C. Gonzalez, Richard E. Woods Digital Image Processing. – New Jersey (USA): Pearson Education, 2008. – 954 p.

2. Шапиро Л. Компьютерное зрение / Л. Шапиро, Дж. Стокман. – М.: БИНОМ, 2006. – 752 с.

3. Milan Sonka, Vaclav Hlavac, Roger Boyle Image Processing, Analysis, and Machine Vision, 4th edition. – Australia: Cengage Learning, 2015. – 920 p.

4. Форсайт Д. Компьютерное зрение. Современный подход / Д. Форсайт, Ж. Понс. – М.: Вильямс, 2004. – 928 с.

5. Smelyakov K.S. Models and methods of segmentation of irregular object images for off-line machine vision systems. – Thesis for Doctor's degree in specialty 01.05.02 – mathematical modelling and computing methods. – Karazin Kharkiv National University, Kharkov, 2012. – 306 p. (In Russian).

6. Яне Б. Цифровая обработка изображений / Б. Яне. – М.: Техносфера, 2007. – 584 с.

7. Смеляков К.С. Анализ эффективности фильтров резкости изображений / К.С. Смеляков, Е.М. Дроб // Системы обработки информации, 2014. – Вип 8 (124). – С. 137-143.

8. Смеляков К.С. Модели и методы сегментации границ изображений нерегулярного вида на основе адаптивных масок: дис. ... канд. техн. наук: 01.05.02 / Смеляков Кирилл Сергеевич. – Х., 2005. – 162 с.

Надійшла до редколегії 24.07.2015

Рецензент: д-р техн. наук, проф. І.В. Рубан, Харківський університет Повітряних Сил ім. І. Кожедуба, Харків.

АДАПТИВНА МОДЕЛЬ ПІДВИЩЕННЯ РІЗКОСТІ ЦИФРОВОГО ЗОБРАЖЕННЯ

К.С. Смеляков, Є.М. Дроб

В роботі пропонується адаптивна модель та метод підвищення різкості об'єктів на цифровому зображенні, використання яких дозволяє значимо знижувати рівні прояву основних недоліків сучасних фільтрів різкості і забезпечувати, таким чином, високий рівень ефективності підвищення різкості цифрового зображення.

Ключові слова: *цифрове зображення, ефективність, адаптація, модель, метод, фільтр різкості.*

АДАПТИВНАЯ МОДЕЛЬ ПОВЫШЕНИЯ РЕЗКОСТИ ЦИФРОВОГО ИЗОБРАЖЕНИЯ

К.С. Смеляков, Е.М. Дроб

В работе предлагается адаптивная модель и метод повышения резкости объектов на цифровом изображении, использование которых позволяет значимо снижать уровни проявления основных недостатков современных фильтров резкости и обеспечивать, таким образом, высокий уровень эффективности повышения резкости цифрового изображения.

Ключевые слова: *цифровое изображение, эффективность, адаптация, модель, метод, фильтр резкости.*