Abstract

A new nonlinear spatial domain image enhancement method based on grey-tone morphological operators and image gradient is presented. The method employs a morphological gradient as it can effectively preserve the details feature of image and it is less sensitive to contour orientations. Image enhancement at the pixels, which have gradient more some threshold, leads to increasing contrast and sharpening image.

1. Introduction

A main goal of image enhancement consists in such image processing that gives resulting image, which is more suitable from concrete application viewpoint. This fact means that enhancement methods are problem-oriented in large measure [1]. The development of image enhancement method from visual interpretation viewpoint is an aim of this paper.

One of the most common image degradations is their poor contrast quality. The crucial task of contrast enhancement is to highlight fine details in image. So far as image sharpness can be defined as edge contrast, hence this process leads to sharpening. Usages of image sharpening include applications from document processing and medical imaging to industrial inspection and autonomous military navigation systems [1, 2]. The sufficient contour sharpness provides contributory visual perception of image. Particularly, identifying the edges of low contrast objects is one of the most significant tasks performed by those interpreting medical images (computed tomography, magnetic resonance, ultrasound, X-rays).

There are existing many effective image contrast enhancement methods [1, 2]. The first, these can be devided on two cathegories: spatial and frequently domain. On the other hand, these can belongs to linear and nonlinear methods. Our proposed method is nonlinear and it operates in spatial domain. The classical spatial methods of image enhancement are linear stretching, gamma correction, histogram equalization, methods of mathematical morphology and other. Despite many methods, contrast task is not solved in full sense. Some methods are buit only for restricted image classes, other need many computations or choosing paremeters, often manually.

Many researchers now hold the view that it is not possible to obtain major breakthroughs in image sharpening without resorting to nonlinear means. Mathematical morphology belongs to a geometrical branch of nonlinear filters [3].

A new nonlinear spatial domain low contrast image sharpening method is proposed in this paper. The method is based on applying grey-tone morphological enhancement operator [4] at image pixels, which correspond to points with gradient more some threshold or even if nonzero. That is to say enhancing are using only at image edges. The edges are considering as boundaries between objects and background. Objects boundaries are often characterized by grey-level intensity transitions. A gradient mask are widely used for detecting these variations. There are many existing effective methods for edge detection such as gradient edge detectors (1st derivative), zero crossing (2nd derivative), Laplacian of Gaussian (LOG), Gaussian edge detectors, grey-tone morphological gradient and other [5]. We use morphological gradient [6] in the proposed method because it can effectively preserve the details feature of image and it is less sensitive to contour orientations, but we take not exeption to using different edge detection operators. The morphological approach to gradients consists in determining a grey level variation within a given neighbourhood using extensive and anti-extensive operators. It can solve the problem of the coordination of edge detection accuracy and anti-noise performance. Morphological gradient has many modifications [7], but we employ original version.

This paper has next organization. Section 2 introduces background of mathematical morphology, particularly contrast enhancement operator, morphological gradient. The proposed method scheme and detail analysis of each blocks are presented in Section 3. Results of computer
experiments are shown in Section 4. Finally, Section 5 contains some concluding remarks.

The experiments, carried out at this paper, show us that the proposed algorithm gives better results, as compared with morphological contrast enhancement at every image pixels. The images, processed by given method, have higher contrast and sharpness. The noise component is evident in less measure on enhanced images. This shows the effectiveness of our algorithm.

2. Background of mathematical morphology

Let us consider both the image and structuring element as grey-tone functions defined as follows:

\[ F : D \rightarrow E, \quad D \subset \mathbb{Z}^2, \quad E = [0, M], \quad M > 0. \]

So far as, we will be work with grey-scale images, then \( M = 256 \). Let introduce grey-tone morphological operations that will be applied in following investigation [1].

Grey-tone morphological dilation for the image \( F \) by flat structuring element \( S \) is denoted \( F \oplus S \) and defined as follows:

\[
(F \oplus S)(x, y) = \max\{F(x-x', y-y') + S(x', y') \mid (x', y') \in D_S\},
\]

where \( D_S \) is a domain of the \( S \). In practice, the grayscale dilation is usually performed using flat structural elements for which 

\[
S(x', y') = 0, \forall (x', y') \in D_S.
\]

In this paper, morphological transformation carried out using flat structural elements. So, in this case dilatation is:

\[
(F \oplus S)(x, y) = \max\{F(x-x', y-y') \mid (x', y') \in D_S\}. \quad (1)
\]

Grey-tone morphological erosion of the image \( F \) by flat structuring element \( S \) at any location \((x, y)\) is denoted \( F \ominus S \) and defined as minimum value of the image in the region coincident with \( S \) when the origin of \( S \) is at \((x, y)\). In equation form, the erosion at \((x, y)\) of image \( F \) by \( S \) is given by

\[
(F \ominus S)(x, y) = \min\{F(x-x', y-y') \mid (x', y') \in D_S\}. \quad (2)
\]

Exist a lot of structuring elements. In this paper the enhancement algorithm is checking using the forms of elements: square, disk, diamond.

Morphological opening of the image \( F \) by the element \( S \) is denoted \( F \circ S \) and defined as:

\[
F \circ S = (F \ominus S) \oplus S. \quad (3)
\]

As before, opening is simply the erosion of \( F \) by \( S \), followed by a dilation of the result with \( S \). Similarly, the closing of \( F \) by \( S \), denoted \( F \bullet S \), is:

\[
F \bullet S = (F \oplus S) \ominus S. \quad (4)
\]

White Top Hat (WTH) operator from an image \( F \) represents contrast between image intensity function and its opening:

\[
WTH(F)(x, y) = F - ((F \ominus S) \oplus S). \quad (5)
\]

Black Top Hat (BTH) transform of an image \( F \) represents the contrast between morphological closing and intensity function \( F \):

\[
BTH(F)(x, y) = ((F \oplus S) \ominus S) - F. \quad (6)
\]

Morphological contrast operator of an image \( F \) represents the addition between the grey-tone function and its WTH transform followed by the difference with its BTH transform[4]:

\[
ContEnh(F) = F + WTH(F) - BTH(F). \quad (7)
\]

The main idea of this enhancement consists in the following: adding WTH to the original image for enhance brights features and substruct BTH from the original image to enhance dark features.

In addition to before-mentioned transforms, dilation and erosion are often used for calculating image morphological gradient. Let denote it by \( G \):

\[
G = (F \oplus S) - (F \ominus S). \quad (8)
\]

The morphological gradient highlights the sharp differences in the brightness of the input image. In getting the morphological gradient are used symmetric primitives, resulting this the gradient is less sensitive to directivity contours.

3. Image sharpening scheme

The following flow chart represents functional scheme of proposed enhancement algorithm.

![Figure 1. The scheme of proposed algorithm (find is a Matlab function)](image-url)
Let us consider performance of each blocks in details. The input of the algorithm is field grey-scale image. There are not any conditions for input image size.

The next step is to calculate morphological gradient image by formula (8). As a result of experiments, it was observed that small gradient values show a slight drop in intensity. Such gradient points are often manifested at noise areas. Therefore, in order to avoid the amplification of contrast in these locations, we offer to introduce some threshold, to reset (truncate) the gradient values, which are less than this threshold.

Experiments show that threshold, for example, you can set 20. Let take a standard image "Lena" and visualizate a initial morphological gradient and truncated gradient for this image (Fig. 2).

![Fig.2. A visualization "Lena" image gradient: a) – original image; b) – original gradient; c) – truncated gradient.](image)

As can be seen from Fig. 2, the image truncated gradient attended less noise, contours boundaries become more sharpen. Maybe for some images it would be wise gradient is smooth, but in general it has not given any thing better outcomes.

The next step of the algorithm is to find the coordinates of the gradient matrix with nonzero values, after which the input image is improved in the corresponding coordinates. Improvements carried out using morphological operator to enhance image quality on the base of contrast that is given by the formula (7).

The operator (7) is designed by logarithmic image processing [4, 8]. This approach is effective in enhancing the entire image, while enhancing only the contours of the current satisfactory results could not be obtained. This may be a direction for future research.

4. Experimental results

Computer experiments were performed in Matlab 7.0, PC with processor Pentium(R) Dual-Core 2.4 GHz, RAM – 2Gb. We demonstrate enhancing by proposed algorithm on two images „Lena” and „Einstein” with size $256 \times 256$ and $460 \times 600$ pixels respectively. These images are shown in Fig 3a, 5a.

Many experiments shown that structuring element “diamond” (with radius 2) is quite useful for sharpening. We used $\text{threshold}=20$ for processing of both images. The enhanced images are presented on Fig. 3c, 5c. These images was enhanced at each pixels by operator (7) too, they are shown on Fig. 3b, 5b.

As one can see, image enhancement using morphological operators (7) gives the best result by the proposed approach (Fig. 3c) compared to enhancement at each point in the image (Fig. 3b). In particular, the images (Fig. 3c, 5c) show less noise component, sharper contours.

Let demonstrate that the enhanced image is characterized less noise component. We show zoom noisy areas of the image from Fig. 3b, 3c.

![Fig.3. Example of image enhancement: a) – original test image "Lena"; b) – enhanced image by operator (7) at each pixel; c) – result of proposed approach.](image)
Fig. 4. Noisy areas of images from Fig. 3: a) – enhanced image by operator (7) at each pixel; c) – result of proposed approach.

The result of the enhancement of next image „Einstein” is presented in Fig. 5.

Fig. 5. An example of image enhancement: a) – original image “Einstein”; b) – enhanced image by operator (7) in each pixel; c) – result of proposed approach.

For better visual effect of processing let consider the fragment of enhanced image “Einstein” in zoom (Fig. 5).

Fig. 6. Enhancing: a) – zoom fragment of original image “Einstein”; b) – zoom fragment of enhanced respectively image.

As one can see, the processed image by proposed algorithm is more sharper and contrasty, especially at the boundaries.

The proposed algorithm for image enhancement was tested on different image classes, particularly X-ray. That also has shown satisfying results.

4. Conclusions

Experimental results show the effectiveness of this approach to enhance the images. In particular the using of the morphological enhancement operator at image pixels, which have nonzero values of gradient allow us to sharp the boundary fragments of image. The modification of proposed algorithm, using logarithmic image processing, can be the subject of our further research.

5. Bibliography And Authors

Bibliography


Author:

MSc. Sergiy Stepanyuk
Lesia Ukrainka Eastern European National University
Potapova street, 9
Lutsk
tel. (097) 455 36 14
e-mail: StepanyukSI@gmail.com

I would like to sincerely thank prof. R. Vorobel for this useful consultations.