Automatic formation of complex image processing algorithms

V.A. Koshcheev
Department of Computer Science and Robotics
Ufa State Aviation Technical University
Ufa, Russia
e-mail: koscheev.vladimir-a@net.ugatu.s

K.F. Tagirova
Department of Computer Science and Robotics
Ufa State Aviation Technical University
Ufa, Russia
e-mail: tagirovakf@yandex.ru

A.M. Vulfin
Department of Computer Science and Robotics
Ufa State Aviation Technical University
Ufa, Russia
e-mail: vulfin.alexey@gmail.com

Abstract[1]

Image pre-processing (sharpening, noise removal, contrast enhancement) for their future classification or recognition can be performed by a large number of different methods. In this paper we propose an algorithm which allows to automatically select a contrast enhancement procedure based on the objective characteristics of the image.

1. Introduction

In the process of solving the tasks of machine perception, the image pre-processing and contrast enhancement in particular are important steps.

For a non-specialist it is usually very difficult to find a correspondence between the actual task of image processing and the corresponding combination of methods and parameters of these methods which would allow for the most efficient solution of this task using available resources.

It can be concluded that standardized solutions and algorithms that accumulate the experience in development and implementation of image processing systems, computer and machine vision, etc., are in demand.

At the moment there are a lot of different contrast enhancement methods, each of which has its own qualities. These methods yield different results which depend both on the processed image and on the selected parameters of these methods [1].

Proceedings of the 6th All-Russian Conference Scientific "Information Technologies for Intelligent Decision Making Support", May 28-31, Ufa - Stavropol, Russia, 2018

2. Methods and definitions used

In this case the objective numerical characteristics of the image are used to select the processing method, namely, analysis of the histogram of the image-difference between the image with the equalized histogram and the original image.

A histogram of a digital image with brightness levels in the range [*0, L-1*] is a discrete function $h(r_k) = n_k$, where r_k is the k-th brightness level, and n_k is the number of pixels in the image with brightness level r_k. The histogram is then usually normalized by dividing each of its values by the total number of pixels in the image $M \cdot N$:

$$n_{nk} = \frac{n_k}{MN}$$

Based only on the information contained in the histogram of the original image it is possible to build a conversion function that automatically achieves the effect of equalization of the histogram.

This results in a more even distribution of brightness levels and stretches the histogram of the original image, so that the brightness levels of the resulting image take a wider range of brightness scales.

The transformation function has the form

$$s_k = (L-1)\sum_{j=0}^{k} p_r(r_j) = \frac{L-1}{MN}\sum_{j=0}^{k} n_j$$

Where L is a number of brightness levels; MN is a number of pixels in the image; $k = 0, 1, \dots, L-1$ is a brightness level; s_k is a brightness value that will be assigned to pixels that previously had a brightness level of k; n_j is a number of pixels with brightness $j \in (0, 1, 2, \dots, k)$.

The second method used is contrast enhancement method based on fuzzy logic [2].

It is possible to formulate the process of increasing the contrasts of a grayscale image using the following fuzzy rules:

- IF the pixel is dark, then make it darker.

- IF the pixel is gray, then make it gray.

- IF the pixel is bright, then make it brighter.

Bearing in mind that these are fuzzy terms, the concepts of dark, gray and bright can be expressed using the membership function shown in Fig. 1.

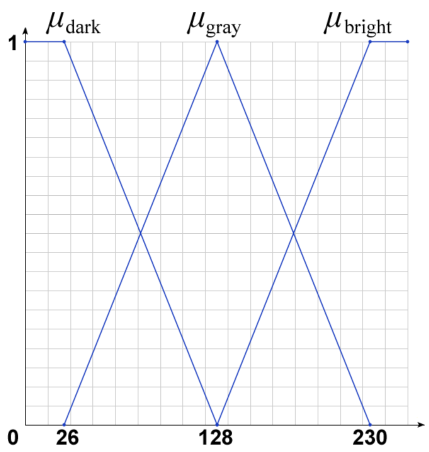

Fig. 1. Input and output functions of the accessory for contrast enhancement based on fuzzy logic

Since we are dealing with constants in the output membership functions, the output v_0 for any input z_0 is given by the formula:

$$v_0 = \frac{\mu_{dark}(z_0)v_d + \mu_{gray}(z_0)v_g + \mu_{bright}(z_0)v_b}{\mu_{dark}(z_0) + \mu_{gray}(z_0) + \mu_{bright}(z_0)}$$

In this case, $v_d = 26, v_g = 128, v_b = 230$ (approx. 10%, 50%, 90% of 255):

$$v_0 = \frac{\mu_{dark}(z_0) \cdot 26 + \mu_{gray}(z_0) \cdot 128 + \mu_{bright}(z_0) \cdot 230}{\mu_{dark}(z_0) + \mu_{gray}(z_0) + \mu_{bright}(z_0)}$$

The price of significant improvement in the results using this approach is high computational complexity.

3. Algorithm description

From a computation complexity standpoint equalization of the histogram is a simple method. In this case it is used not only as a method of contrast enhancement, but also as one of the steps for evaluating the characteristics of image. Depending on the result, the algorithm decides whether to use a more costly method based on fuzzy logic.

The scheme of the algorithm is shown in Fig. 2. The algorithm is described by the following sequence:

1) The histogram of the original image f is equalized. Denote the resulting image by g_{eq}.

2) A histogram of the difference between the resulting and the original images $g_{eq} - f$ is built.

A large number of "bright" pixels in the image-difference generally is a sign of the negative influence of the histogram equalization procedure on the contrast and image quality in general (i.e. there might be an emphasis on background of the image and/or large uninformative details).

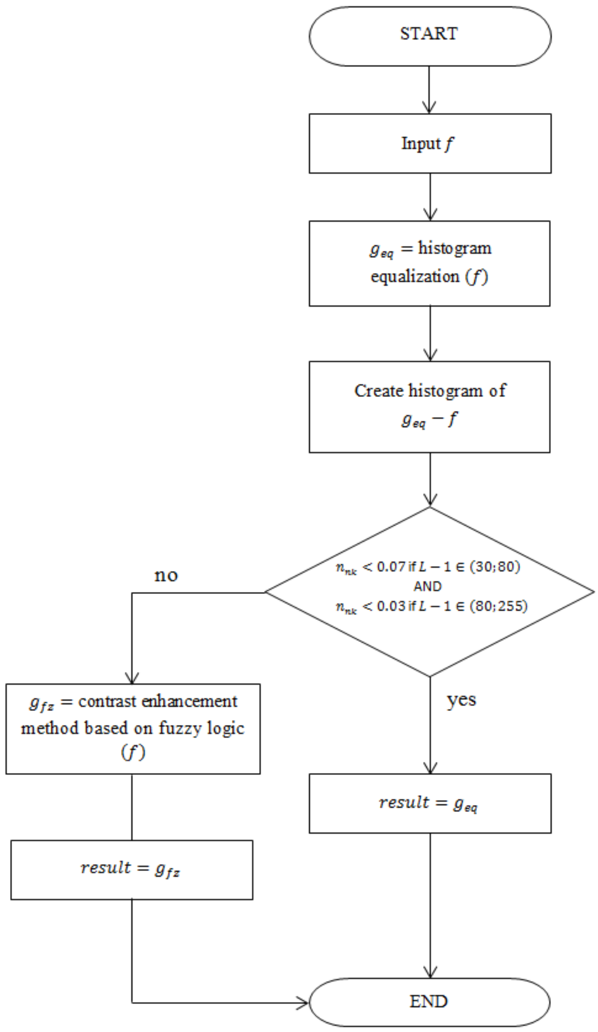

Fig. 2. Scheme of the algorithm

If the histogram of difference $g_{eq} - f$ goes beyond the ranges

$$n_{nk} < 0.07 \text{ if } L - 1 \in (30; 80)$$

$$n_{nk} < 0.03 \text{ if } L - 1 \in (80; 255)$$

this is highly likely an indication that the histogram equalization negatively affected the image quality (Figure 3), and it is more appropriate to use a complex method. The boundaries of the ranges were determined empirically.

Otherwise (if the histogram of the difference $g_{eq} - f$ lies inside the ranges), the result is the image g_{eq} and the algorithm stops.

3) Thus, if the histogram of the difference $g_{eq} - f$ goes beyond said ranges, a costly method of contrast enhancement based on fuzzy logic is used.

An example of its use is shown in Fig. 4.

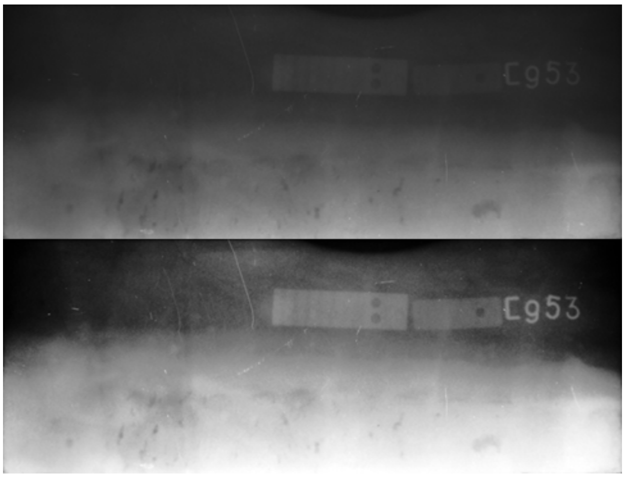

Fig. 3. An example of image quality degradation after using the histogram equalization method

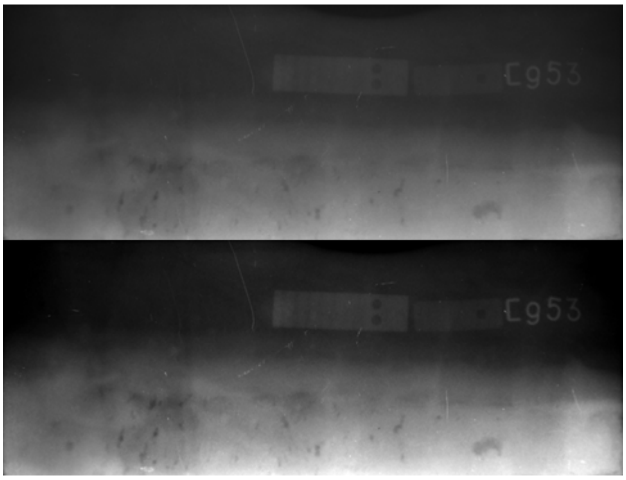

Fig. 4. Application of contrast enhancement method based on fuzzy logic to the previous image

4. Conclusion

Contrast enhancement almost always precedes the use of various intellectual methods and their automatic selection allows to increase the efficiency and quality of the segmentation and recognition of the objects of interest (both by machine and human).

Using the proposed algorithm allows to automatically decide whether to use the equalization of the histogram to improve the contrast of the input image, or whether it is better to resort to a more resource-intensive method based on fuzzy logic rules.

References

1. D.A. Kolchaev Automatic adjustment of image processing pipeline / D.A. Kolchaev, E.R. Muratov, M.B. Nikiforov // 3rd International conference "Information Technology and Nanotechnology 2017"
2. Digital image processing (3th Edition) / R. Gonzales, R. Woods — M.: Technosphera, 2012. – 1104 p.