The algorithm of formation of a training set for an artificial neural network for image segmentation

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Abstract

This article suggests an algorithm of formation a training set for artificial neural network in case of image segmentation. The distinctive feature of this algorithm is that it using only one image for segmentation. The segmentation performs using three-layer perceptron. The main method of the segmentation is a method of region growing. Neural network is using for get a decision to include pixel into an area or not. Impulse noise is using for generation of a training set. Pixels damaged by noise are not related to the same region. Suggested method has been tested with help of computer experiment in automatic and interactive modes.

Keywords: image segmentation, artificial neural networks, impulse noise

1 Introduction

Image segmentation is one of the variants of the task of clustering a set of pixels on the basis of color affinity. It should be pointed out that the segmentation problem does not have an exact solution and the effectiveness of the decision is usually evaluated on the basis of comparison with the results obtained by experts in manual mode. That means that the effectiveness of the segmentation cannot be unambiguous. One of the approaches actively developing in recent few years is the use of artificial neural networks. However, this approach faces the problem of the formation of a learning set. If there is a series of similar images, for example, with medical information, then the problem is solved quite simply. But if the task is to segment one single image, which has no analogues, then the traditional approaches face unsolvable difficulties. To solve the image segmentation problem, various artificial neural networks were used. There were built algorithms based on the multilayer perceptron \cite{1}, as well as its modifications using cross entropy \cite{2}, genetic algorithms \cite{3, 4}, regions growing \cite{5, 6}, minimal difference ratio \cite{7}, wavelet decomposition of the original image \cite{8}. Additionally, multilayer perceptron was
used in conjunction with other segmentation algorithms, for example, the k-means method [9]. A number of algorithms were also developed on the basis of Kohonen self-organizing maps [10, 11, 12]. As well as for a multilayer perceptron, there are some algorithms were proposed to combine Kohonen maps with other segmentation algorithms the hybrid genetic algorithm [13], the k-means method [14], the growing of the regions [15]. All the algorithms listed above has specialized nature and oriented to images of a certain type. This specialization is necessary for the formation of a learning set. Neural networks trained on the one type of images do not work for other types of images. In this paper, we propose an algorithm for forming a learning set in a segmentation problem that is oriented to one particular image and does not require an additional set of similar images.

2 The formulation of the problem and the solving method

The image segmentation algorithm will be based on the method of growing areas, which has proved to be very useful when using graph representation of the image [16, 17]. Growing a segment starts from a single point selected randomly on the raw portion of the image. At the initial point in time, the whole image is considered unprocessed. All points attached to one of the segments are considered to be the processed part of the image. Segment growing occurs by attaching new points to it. The algorithm traverses the boundary points of the already formed part of the segment and pairwise processes them with neighboring points that are not part of the segment. For each such pair, a decision is made whether to join or not to the segment. They join the segment of the point according to the color characteristics similar to those already included in it. For each segment, a unique label is used, represented by a natural number. The raw part of the image is marked with a zero value. Thus, at each stage of the algorithm work, all the image points are associated with some labels. At the initial time all points have a zero mark. At the end of the algorithm all points are aligned with nonzero labels. To make a decision on the similarity of two points, a three-layer perceptron was used. The points were compared by their color coordinates in the RGB model. Since the comparison occurs only for two points, the input layer of the perceptron has six neurons corresponding to the color coordinates of the points. The output layer contains two neurons, corresponding to a positive and negative decision about the similarity of points. In the framework of a computer experiment, it was
determined that the algorithm’s efficiency increases with the increase in the number of neurons in the hidden layer down to a value of 50, after which it remains unchanged. Therefore, in the future, a three-layer perceptron with fifty neurons in a hidden layer was used. Assume that there is an image that has $N \times M$ pixels which in the RGB model can be represented with a three matrices $||R_{ij}||$, $||G_{ij}||$, $||B_{ij}||$ ($i = 1, ..., N; j = 1, ..., M$), that corresponds to a color components red, green and blue respectively. Lets introduce a notation $v_{ij}$ for a pixel with coordinates $(i, j)$:

$$v_{ij}.r = R_{ij}, \quad v_{ij}.g = G_{ij}, \quad v_{ij}.b = B_{ij}. \quad (1)$$

For the matrix of marks let’s introduce a notation $C_{ij}$ ($i = 1, ..., N; j = 1, ..., M$). Let’s use a notation $v_{ij}.c = C_{ij}$ for a mark of some specific pixel.

Let’s inspect the algorithm of region growing. Assume that there are $k$ segments are found at the moment. Let’s get a random point from the set of pixels with zero mark and demote it by $v_{ij}$. Changing the mark of this pixel: $v_{ij}.c = k + 1$. Now let’s run the following recursive algorithm:

1. Assume the growing segment contain $r$ pixels $\{v_1, ..., v_r\}$.

2. Traverse all neighbours of the pixels with zero mark that are included into the segment.

3. Generating an input vector of the neural network using values of color components of a point of the segment $v$ and its nearest neighbour $v'$ that not included to the segment:

$$(v.r, v.g, v.b, v'.r, v'.g, v'.b). \quad (2)$$

4. Calculating output value of the neural network. If the decision is positive, change the mark of point $v'$: $v'.c = k + 1$. If the decision is negative, continue with next neighbour point that is not included to the segment.

5. The algorithm stops when there are no positive decisions for all nearest neighbours.

Segmentation of the image is completed when there are no points with zero mark. The algorithm will have a linear complexity such as it iterates all pixels that has not more then eight nearest neighbours.
The efficiency of the algorithm is significantly depends on the training of the neural network, which is determined by a training set. Let’s form a training set for a single image by using of artificially generated impulse noise. A pseudo-random generator sequences with uniform distribution will be used. Based on this generator, let’s generate a new color coordinates for p% pixels of the original image. The coordinates will be select randomly, and a new color will be choose so that it is significantly differed from the original. Assume that the entire color palette contains m colors. If in the original image for a random pixel with coordinates (i, j) one of the color coordinates having the value $m_{ij} > m/2$, then let’s select a new color from the interval $[0, m/2)$. For the case $m_{ij} \leq m/2$ the new color is chosen from the interval $(m/2, m - 1]$. As a result of this modification it can be considered that the modified pixel can not be combined into one segment with the nearest neighbours. Changed pixels playing the main role in the training set. As the computer experiment has shown, it is necessary to select the value $p \leq 10\%$. To form a training set of a larger volume, it is necessary to repeat the procedure of impulse noise formation on the main image repeatedly. Neural network training has been performed using the method of back propagation of errors. The main disadvantage of this approach to the formation of the training set is that result set contain only negative decisions.

### 3 Computer experiment

During the computer experiment there is an image segmentation of the images with the depth of the palette of each color $m = 256$ has been performed. There are 10% of damaged pixels were generated and this generation has been performed 100 times. The algorithm was tested both in automatic and in interactive modes. In automatic mode, all segments of the image were determined. In the interactive mode, a single segment was searched that contained a user-defined point.

An example of how an algorithm works in automatic mode is shown in Figure 1, which shows contours of the segments. Figure 2 shows the result of the algorithm in interactive mode.
Conclusion

Despite the existing shortcomings in the formation of the training set, the proposed algorithm allows the segmentation of a given image with a neural network without involving other images that are close in structure. A computer experiment showed that the proposed algorithm is most effective in the case of clear contours and segments of large size. Next, note that this property is inherent in all segmentation algorithms. However, it is necessary to note the stability of the proposed segmentation algorithm to the impulse noise, which is easily determined by the trained neural network, like segments with a size of one pixel. In the future, this approach can be used with other more efficient neural networks.

Also, the proposed algorithm has good speed due to the linear complexity. The main time is spent on the formation of training set and training of an artificial neural network. The segmentation process on an already trained neural network is much faster. The total processing time of the image size $256 \times 256$ pixels is about 40 seconds.

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Figure 1: Examples of automatic segmentation of the images.
Figure 2: Example of algorithm result using interactive mode on the image "Plane"