Estimating the Usefulness of Preprocessing in Colour Image Segmentation

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Abstract

In the paper we address the problem of usefulness of colour image filtering before segmentation. Our interests are limited to non-linear colour filters working in the spatial domain. Most often comparing such filters is based on calculation of different quality factors (e.g. SNR, NCD etc.). The main idea of this paper is to use an evaluation function, coming from segmentation, to estimate the usefulness of preprocesing. The experiments were realized using both original and noisy images corrupted by Gaussian and impulsive noise.

Introduction

In the case of noisy images different filters can be applied as pre-processing algorithms for colour image segmentation. The performance of filters can be evaluated visually or quantitatively using e.g. peak signal-to-noise ratio PSNR or NCD (normalized colour difference) values. The other possibility is to evaluate segmented images. The application of such preprocessing algorithms may significantly improve segmentation results and therefore their effects on the segmentation results are studied.

We use four types, described in literature, nonlinear colour filters, two different segmentation techniques and one postprocessing algorithm. The usefulness of preprocessing is checked by using the group of ten popular colour images in their original and noisy versions. A special quality function is applied for estimating the usefulness of preprocessing.

This paper is organized as follows. In the next section, a short overview of filters used in paper as preprocessing algorithms is presented. The following section briefly describes two colour image segmentation techniques (mean shift and region growing without seeds). Then a technique optionally used for postprocessing is presented. Next section treats quantitative evaluation of image segmentation results. The last section contains the results of experiments. A short discussion at the end of paper is given.

Preprocessing Algorithms

Different colour filters have beeen developed to suppress noise and preserve edges. The filters achieve a goal that the image is more homogeneous while the edges are still preserved. It is very important to preserve the edges and corners. Unfortunately most commonly used linear smoothing filters smooth images but together blur the edges. Non-linear filters preserve edges and details and remove Gaussian and impulsive noise. For our research we have chosen following four nonlinear colour filters:

(1) SNN (Symmetric Nearest Neighbour Filter) described in Ref. [1],
(2) KuNa (Kuwahara-Nagao Filter) proposed in seventies.[2,3]
(3) PGF (Peer Group Filtering) presented in Ref. [4],
(4) DPA (Digital Paths Algorithm) suggested in Ref. [5].

We used most typical versions of filters working with 3x3 masks. We have limited the number of iterations for each filter to only one.

In the case of SNN filter the neighbours of the central pixel in a window are considered as four pairs of symmetric pixels: N-S, W-E, NW-SE and NE-SW. For each pair the pixel closest in colour to the central pixel is selected. The colours of these four selected pixels are averaged and the mean colour value is a new colour for central pixel.

The construction of Kuwahara-Nagao filter is similar to that of SNN. The 3x3 mask is splitted into four 2x2 slightly overlapping windows with the mask's central pixel as a common part. For each window the sum of variances of colour components is calculated. The mean colour value of the window with minimal sum of variances (maximal homogeneous region) is used as the output value of the central pixel. The Ku-Na filter needs more computation time than the SNN filter.

The PGF filter finds for each pixel a group of neighbours (peer group members) based on its colour similarity and replace this pixel with its mean colour value. Averaging over the peer group instead of entire mask allows avoiding edge blurring. The main advantage of PGF filter is that PGF determines the corrupted pixels before replacing.

The DPA filter is based on general concept of digital paths in filtration mask. Digital path models a random walk of virtual particle on the two-dimensional lattice. The new colour for central pixel of mask is calculated as weighted arithmetical mean of colours in mask. The weights are defined by a similarity function between points connected by digital paths.

Most of these edge-preserving smoothing filters lead, in opinion presented in the literature, to the good segmentation results.

Segmentation Techniques

The first technique is a clustering technique based on the mean shift idea, which has been used for clustering tasks by Cheng.[6] Colours of the image pixels create a multivariate probability distribution. The local modes of its probability density function correspond to cluster centres. The main idea of mean shift is to shift iteratively a fixed size window (a sphere of radius R) to the mean of the points within it. It estimates the gradient of density function. The centre of the sphere is then placed at this mean, and the algorithm is iterated until convergence. The shifts are in the direction of a maximum of density function and they are large in low-density regions and small near local maxims. The procedure is guaranteed to converge and does not need any knowledge about the number or the shape of clusters.

The second technique is based on the concept of region growing without seeds needed to start the segmentation process.[7] At the beginning of the algorithm each pixel has its own label (one-pixel regions). The concept of 4-connectedness is used for its computational simplicity. For region growing process is used the centroid linkage strategy. This strategy includes a pixel in the region if it is 4-connected to this region and has colour value in the specified range from the mean colour of an already constructed region. After inclusion of pixel the region's mean colour is updated. For this updating recurrent formulae are used. Two simple raster scans of the colour pixels are employed: from left to right and from top to bottom. The segmentation results are strongly determined by a tuning parameter: threshold d, which limits the value of homogeneity criterion. The version of algorithm used here works in RGB colour space.

Postprocessing Algorithm

The segmented image can be further postprocessed e.g. by removing small regions that are usually not significant in further stages of image processing.[8] Postprocessing needs additional pass from the top left corner of the image to the bottom right corner, whose aim is to remove the regions, which consist of a number of pixels smaller than a certain threshold. During this merging process each region with a number of pixels below a specified threshold $\boldsymbol{A}$ is merged into a region with a larger area and nearest in the sense of colour distance. After the merging, a new mean color of region is calculated and the labels of pixels belonging to a region are modified. The pre-selected size of removed regions $\boldsymbol{A}$ plays a role of control parameter.

Estimating the Usefulness of Preprocessing

In literature exist a few methods of quantitative evaluation of image segmentation results, which for lack of general image segmentation theory are very usefull in practical applications. Borsotti et al.[9] have proposed and tested following quality function Q:

$$Q(I) = \frac{1}{10000\,(N \cdot M)} \sqrt{R} \sum_{i=1}^{R} \left[\frac{e_i^2}{1 + \log A_i} + \left(\frac{R(A_i)}{A_i} \right)^2 \right] \qquad (1)$$

where: I is the segmented image, $N{\cdot}M$, size of the image, R, the number of regions in the segmented image, A_i, the area of pixels of the ith region, and e_i the colour error of region I and $R(A_i)$ is the number of regions with area equal to A_i.

First term of equation (1) is a normalization factor, the second term penalizes results with too many regions (oversegmentation), the third term penalizes results with non-homogeneous regions. Last term is scaled by the area factor because the colour error is higher for large regions. The colour error in RGB space is calculated as the sum of the Euclidean distances between colour components of pixels of region and components of average colour, which is an attribute of this region in the segmented image. More information about inspiration in building of this function is in Ref. [9].

Evaluation function $Q(I)$ good conforms to the visual judgement. The idea of using this function can be formulate as: the lower the value of $Q(I)$, the better is the segmentation result. We used this function for performing experimental investigations, described below.

Results of Experiments

Figure 1 shows reduced versions of 10 popular test images used during this work.

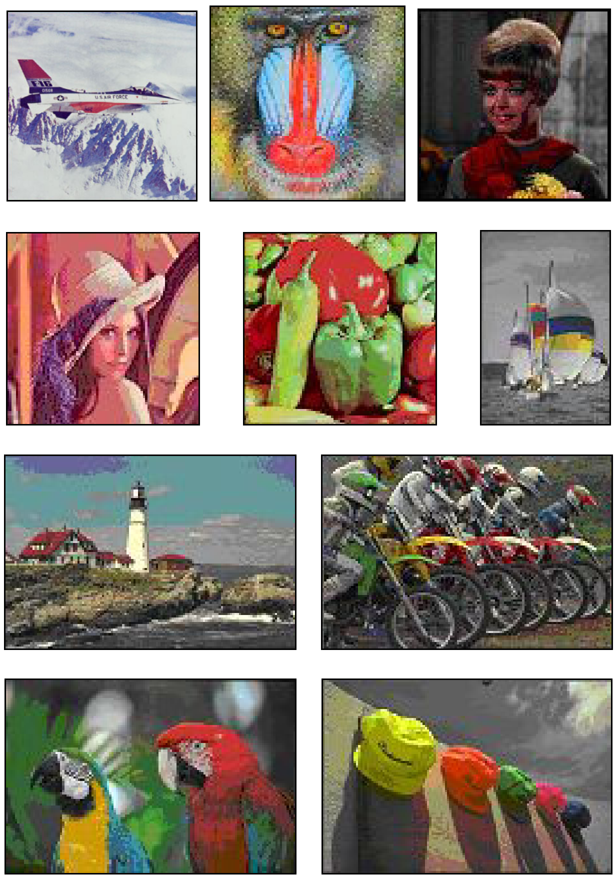

Figure 1. Test images used in the experiments

In order to estimate the usefulness of colour filters an experiment with original (relatively noise-free images) has been carried out. For each segmented image, the Q(I) value was calculated and averaged for the whole group of images. Figure 2 presents the results of experiment. Average Q(I) values for each segmentation technique were normalized for comparison purposes.

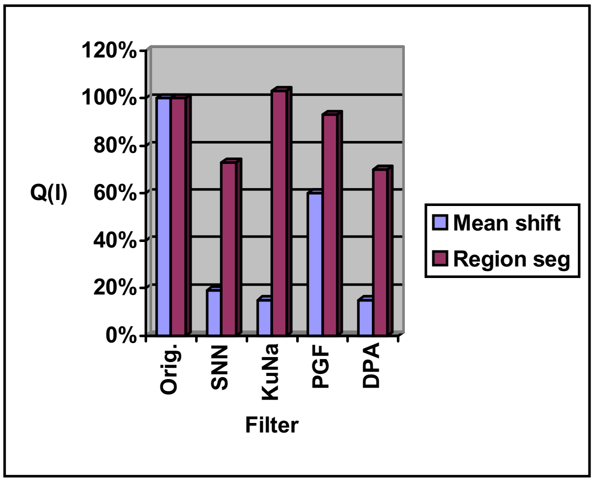

Figure 2. Average Q(I) function values for original images

The more effective a filter is, the more decrease the Q(I) value. Results indicate that for region-based segmentation the preprocessing has very limited impact on the segmentation results. On the other hand, in the case of mean shift segmentation the sense of preprocessing is important. In both cases the DPA filter outperform other compared filters.

In the next experiment noisy colour images were used. Original images were corrupted with mixed Gaussian additive (σ=7,5) and impulsive noise (p=0.1 and p1=p2=p3=0,02). Details of the application this impulsive noise model in colour image processing are presented in Ref. [10]. Results from Fig.3 show that in this case all filters are very useful and can be used to enhance the segmentation results. The biggest enhancement is after application of DPA filter.

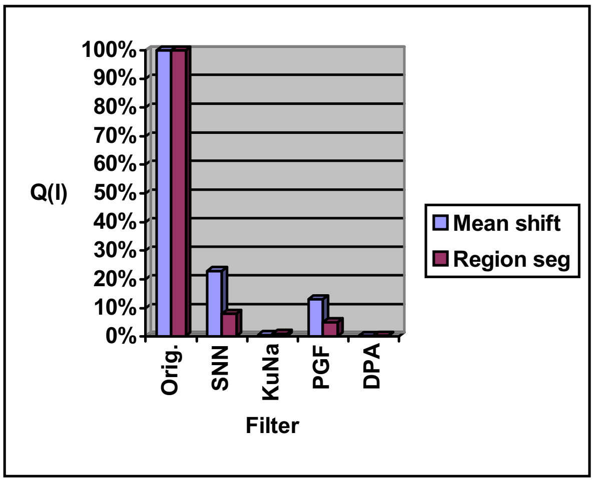

Figure 3. Average Q(I) function values for noisy images

In the majority of investigated cases, the absolute values of Q(I) were smaller for the region-based segmentation. It means that this technique is better than the mean shift technique. The noisy images after segmentation can be improved by using the postprocessing algorithm. Fig.4 presents adequate quality function values. The results changed drastically: as the issue of postprocessing the Q(I) values generally increase and in this case the preprocessing is useless.

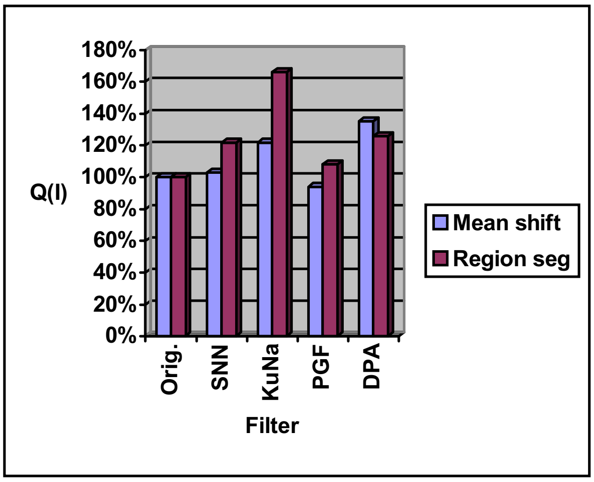

Figure 4. Average Q(I) function values for noisy images and postprocessing

Conclusion

We have shown that quality function Q(I) can be used not only for comparison segmentation techniques but also for estimating the usefulness of preprocessing in colour image segmentation. The methodology for such estimating is proposed. Effectiveness of filtering before segmentation is particularly limited in the case of good original images segmented by region-based method. The comparison of preprocessing filters shows that DPA filter outperforms other tested filters. In the case of using postprocessing based on removing small regions, the application of preprocessing filter can be useless.

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Biography

Henryk Palus received his Ph.D. in Engineering from the Silesian University of Technology (STU) in Gliwice, Poland in 1990. He is an Assistant Professor in the Department of Automatic Control at the Silesian Technical University in Gliwice. The interests of Dr. Palus include the problems of colour in image processing and computer vision, robot vision and multimedia technology. He is an Advisory Editor of *Machine Graphics and Vision* and charter-member of the Polish Association of Image Processing (IAPR member).