REGION-BASED COLOUR IMAGE SEGMENTATION

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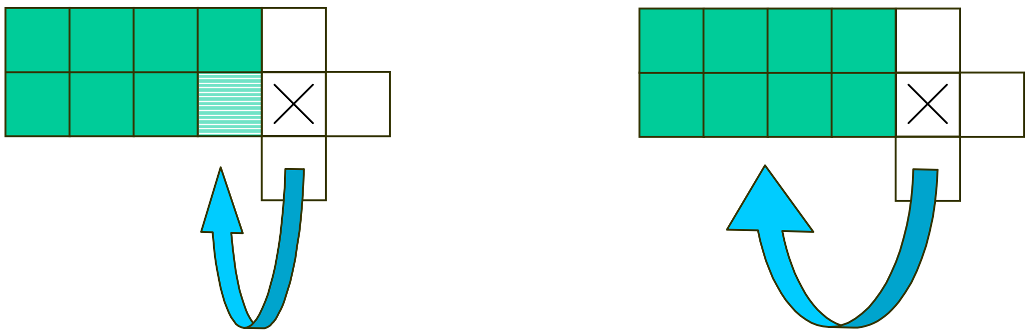
ABSTRACT

The paper presents a method for colour image segmentation based on a region growing procedure. The algorithm works without a priori knowledge about the number of regions in the image. The similarity of colour pixels is modelled by distance in different colour spaces (RGB, YUV and IHS). Additional median filtering and small region elimination procedures are investigated. The operation of algorithm for other variants of the RGB/IHS transformation is checked. The presented method of colour image segmentation is tested on real world images.

1. INTRODUCTION

Accurate and automated segmentation plays an important role in the image processing systems, as error in this process will be propagated further. The general purpose of the colour image segmentation is to arrive at results insensitive to shadows, changes in lighting intensity and surface reflection properties (e.g. highlights). The region-based image segmentation creates regions by grouping together similar pixels with higher accuracy than pixel-based segmentation algorithms. The region growing method, proposed just thirty years ago [1] for grey level images, is nowadays used efficiently for colour image segmentation. The idea of region growing is one of the most fundamental concepts used in image segmentation techniques [2]. Individual pixels (sometimes called seeds) are merged if their attributes (grey level, colour or texture etc.) are similar enough. Colour similarity can be established by computing the value of a homogeneity criterion. Each tested pixel is compared to its immediate neighbouring regions. If a homogeneity criterion is fulfilled then the tested pixel belongs to region and all attributes of region are updated. If a homogeneity criterion is not fulfilled then the tested pixel with a new label starts as a new region. The process of growing is continued until all pixels in image merge in regions as homogeneous as possible. Region growing is a bottom-up segmentation technique that can use different criteria for measurement of region homogeneity [3]. These criteria are crucial in determining the segmentation results. Some papers on region growing in different colour spaces were published in recent years e.g. in RGB colour space [4], IHS colour space [5], HSV colour space [6], HVC colour space [7] and Munsell colour system [8].

Typical region growing procedure is started by finding seeds. This procedure is named *seeded region growing* (SRG) [9] and was used for segmenting of colour image sequences [10]. The improved and pixel order independent version of the SRG algorithm has been lately developed [11]. Here proposed procedure does not use special regions or pixels (seeds) to start the segmentation process. A simple raster scan of the colour pixels is employed: from left to right and from top to bottom. 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. There exist different strategies of pixel linkage. Two main strategies are: *single linkage* and *centroid linkage*. The idea is illustrated in Fig.1. The single linkage strategy includes a pixel in the region if it is 4-connected to this region and has colour value in the specified range from neighbouring pixels (one or more) already included in region. The centroid linkage 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 the mean colour is updated. For this updating recurrent formulae are used.



a) b)

Fig.1 Strategies of pixel linkage: a) single linkage, b) centroid linkage.

Formulae updating of colour mean values are typical and simple, e.g. for the intensity I:

$$\bar{\mathbf{I}}_{\mathbf{n}} = \frac{(\mathbf{n}-1)\,\bar{\mathbf{I}}_{\mathbf{n}-1} + \mathbf{I}_{\mathbf{ij}}}{\mathbf{n}} \qquad (1)$$

where $\bar{\mathbf{I}}_{\mathbf{n}}$ is the new (updated) mean I value of the region, $\bar{\mathbf{I}}_{\mathbf{n}-1}$ is the mean I value of the region before adding a pixel with intensity $\mathbf{I}_{\mathbf{ij}}$ and $\mathbf{n}$ is a number of pixels of the region (together with new attached pixel). For reason of angular nature of hue calculating mean H value is more complicated. First of all hue values are converted into two Cartesian coordinates:

$$\mathbf{x}_{\mathbf{ij}} = \mathbf{cos}\,\mathbf{H}_{\mathbf{ij}}\ ,\ \mathbf{y}_{\mathbf{ij}} = \mathbf{sin}\,\mathbf{H}_{\mathbf{ij}} \qquad (2)$$

Common arithmetic averaging is concern of these coordinates. The means x value and y value are used with the aid of arctg function for computing mean **H** value.

In next considerations we use the centroid linkage strategy only. The results are presented as a map of boundaries of the regions and black lines on a white background are used to show the separated regions.

In this paper we investigate: some homogeneity criteria in different colour spaces with different metrics, an additional region elimination procedure and the operation of algorithm for other variants of the RGB/IHS transformation. The presented method of colour image segmentation is tested on real world images.

2. RESEARCH ON HOMOGENEITY CRITERIA

Homogeneity criteria for colour image segmentation can be applied by using different colour spaces and different metrics. For example:

• criterion defined in the RGB colour space (**RGB-criterion**):

$$\sqrt{(\mathbf{R}-\overline{\mathbf{R}})^2+(\mathbf{G}-\overline{\mathbf{G}})^2+(\mathbf{B}-\overline{\mathbf{B}})^2} \leq \mathbf{d_1} \tag{3}$$

where **R, G, B** are current values of colour components of tested pixel, $\overline{\mathbf{R}}, \overline{\mathbf{G}}, \overline{\mathbf{B}}$ are mean values relate to a region and $\mathbf{d_1}$ is tuning parameter, which determine the segmentation results.

Below two homogeneity criteria based on Y,U,V components are proposed:

• criterion defined on the UV-plane (**UV-criterion**):

$$\sqrt{(\mathbf{U}-\overline{\mathbf{U}})^2+(\mathbf{V}-\overline{\mathbf{V}})^2} \leq \mathbf{d_2} \tag{4}$$

• criterion defined in the YUV space (**YUV-criterion**):

$$\sqrt{(\mathbf{Y}-\overline{\mathbf{Y}})^2+(\mathbf{U}-\overline{\mathbf{U}})^2+(\mathbf{V}-\overline{\mathbf{V}})^2} \leq \mathbf{d_3} \tag{5}$$

where **Y, U, V** are current values of colour components of tested pixel and $\overline{\mathbf{Y}}, \overline{\mathbf{U}}, \overline{\mathbf{V}}$ are mean values relate to a region. The RGB/YUV transformation is linear and defined as [12]:

$$\mathbf{Y} = \mathbf{0.299R} + \mathbf{0.587G} + \mathbf{0.114B} \tag{6}$$

$$\mathbf{U} = -\mathbf{0.147R} - \mathbf{0.289G} + \mathbf{0.437B} \tag{7}$$

$$\mathbf{V} = \mathbf{0.615R} - \mathbf{0.515G} - \mathbf{0.100B} \tag{8}$$

where **Y** is the luminance component and the **U** and **V** are the chrominance components.

Also four different homogeneity criteria based on I,H,S components are presented:

• intensity-based criterion (**I-criterion**):

$$\left|\mathbf{I}-\overline{\mathbf{I}}\right| \leq \mathbf{d_4} \tag{9}$$

• criterion defined on the HS-plane (**HS-criterion**):

$$\sqrt{\mathbf{S}^2+\overline{\mathbf{S}}^2-\mathbf{2S\overline{S}\cos}\left(\mathbf{H}-\overline{\mathbf{H}}\right)} \leq \mathbf{d_5} \tag{10}$$

• criterion defined in the IHS space (**IHS-criterion**):

$$\sqrt{(\mathbf{I}-\overline{\mathbf{I}})^2+\mathbf{S}^2+\overline{\mathbf{S}}^2-\mathbf{2S\overline{S}\cos}\left(\mathbf{H}-\overline{\mathbf{H}}\right)} \leq \mathbf{d_6} \tag{11}$$

Mean values relate to a region whereas current values relate to the tested pixel. In formulae (10) and (11) we are taking into account the cylindrical character of HS components (H is an angle, S is a distance). The IHS-criterion merges all three colour components. All above-mentioned tuning parameters (d_1, d_2, d_3, ...) which determine the segmentation results have to be set by user before segmenting process. The RGB/IHS transformation is non-linear and in „classical" version is defined as [12]:

$$\mathbf{I} = \frac{(\mathbf{R}+\mathbf{G}+\mathbf{B})}{\mathbf{3}} \tag{12}$$

$$\mathbf{H} = \mathbf{arccos}\left(\frac{\mathbf{0.5((R-G)+(R-B))}}{\sqrt{\mathbf{(R-G)^2+(R-B)(G-B)}}}\right) \tag{13}$$

if B > G, then: H := 360°- H

$$\mathbf{S} = \mathbf{1} - \mathbf{3}\frac{\mathbf{min\{R,G,B\}}}{\mathbf{R+G+B}} \tag{14}$$

A number of experiments have been performed using the homogeneity criteria described above. Among tested homogeneity criteria distinctly best results gives the HS-criterion with Euclidean distance metric in cylindrical co-ordinate system (Fig.2 f). Although the algorithm with the RGB-criterion segments out the objects, the results are not impressive; the edges are very noisy (Fig.2 b). The results of using UV- and YUV criteria (Fig.2 c,d) are similar to results generated using IHS space (Fig.2 g): in some number of cases the shadow regions have been introduced. The I-criterion shows limitations, because different adjacent colours can have the same intensity and adequate regions are merged in one common region. Furthermore the shadows on the uniform background generate many regions with different intensity values (Fig.2 e).

In each case the segmentation results are strongly determined by a tuning parameter. Too low value of this parameter leads to oversegmentation and too high value leads to undersegmentation.

3. ELIMINATION OF THE SMALL REGIONS

Very often the region growing algorithm generates too many segments (oversegmentation). There is possible to limit a number of segments by different additional pre-processing and post-processing procedures. Good example for pre-processing is the median filtering before image segmentation. This filtering procedure significantly decreases the number of regions in segmented image (Fig.3). Also, the region merging procedure as post-processing procedure can be used to avoid oversegmentation (Fig.4) or remove small highlights from objects (Fig.5). This procedure locates all regions smaller than a given area, analyses their 4-connected neighbourhood and merges each region with most similar region from its neighbourhood.

4. USE OF OTHER VARIANTS OF THE RGB/IHS TRANSFORMATION

Experimental investigations of presented algorithm were also performed using other variants of the RGB/IHS transformation. Besides the "classical" version of IHS space, Bajon's transformation, HSV and HLS models [12] are tested too. The results are generally similar except result for HLS model that is insensitive to shadows (Fig.6).

5. CONCLUSIONS

We have proposed a centroid linkage region growing algorithm working in different colour spaces. The homogeneity criteria, defined in RGB, YUV and IHS colour spaces, have been tested. In general, the criteria based on IHS space generated better results than the criteria based on RGB and YUV spaces. An additional small region elimination procedure removes oversegmentation results and small highlights. The segmentation algorithm operates without problems using other variants of the RGB/IHS transformation.

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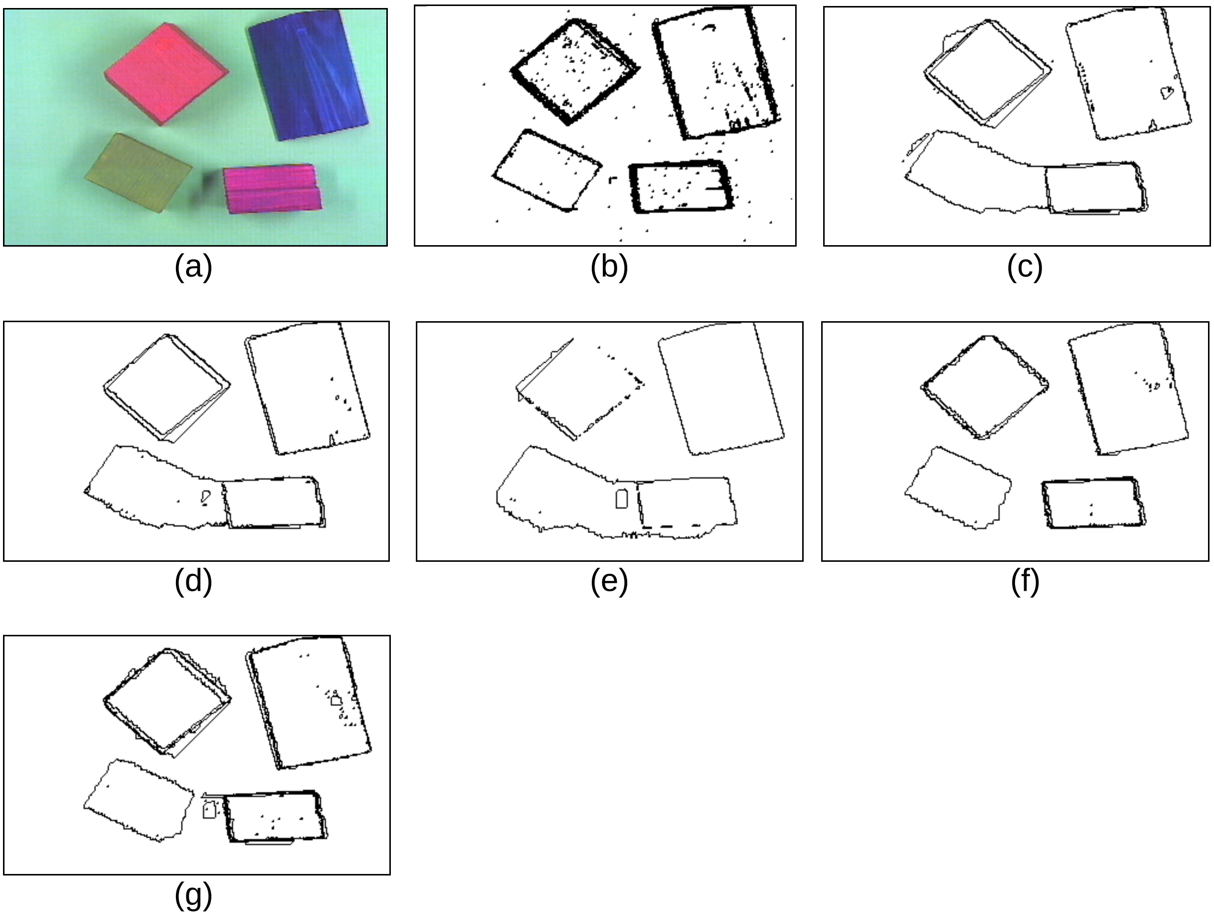


Fig.2. Segmentation results: (a) original colour image, (b) region boundary map for the RGB-criterion, (c) region boundary map for the UV-criterion, (d) region boundary map for the YUV-criterion, (e) region boundary map for the I-criterion, (f) region boundary map for the HS-criterion, (g) region boundary map for the IHS-criterion.

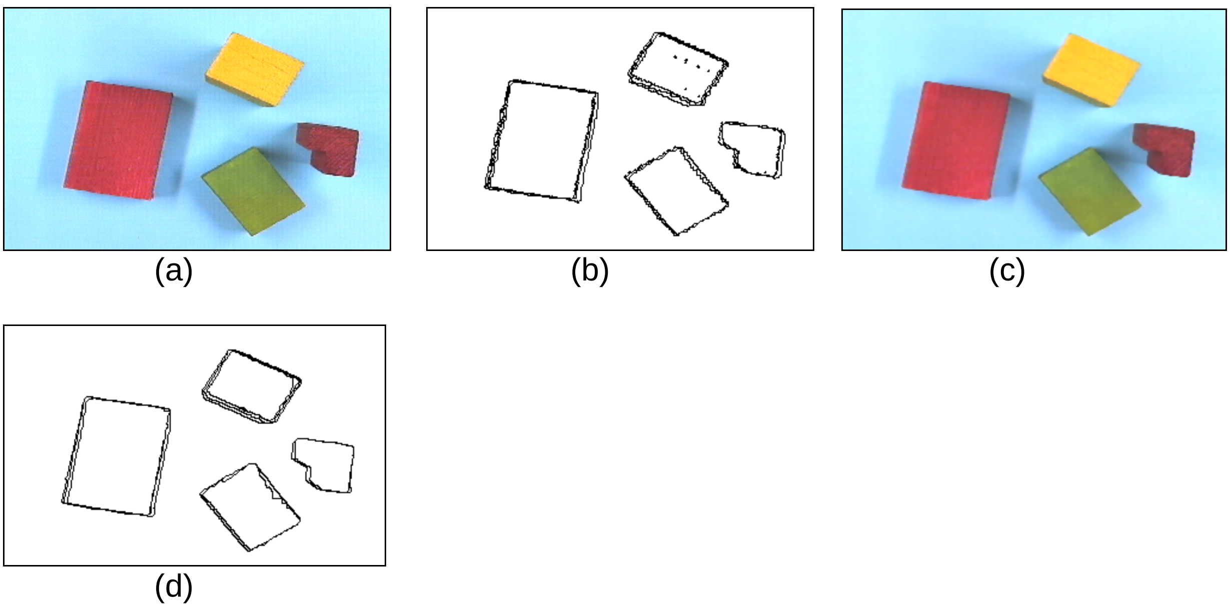
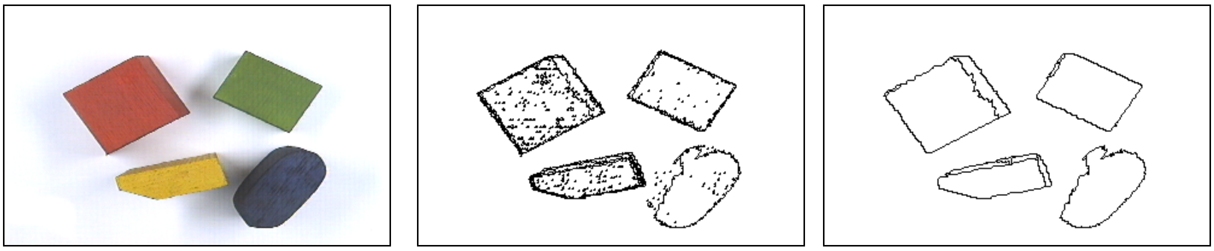
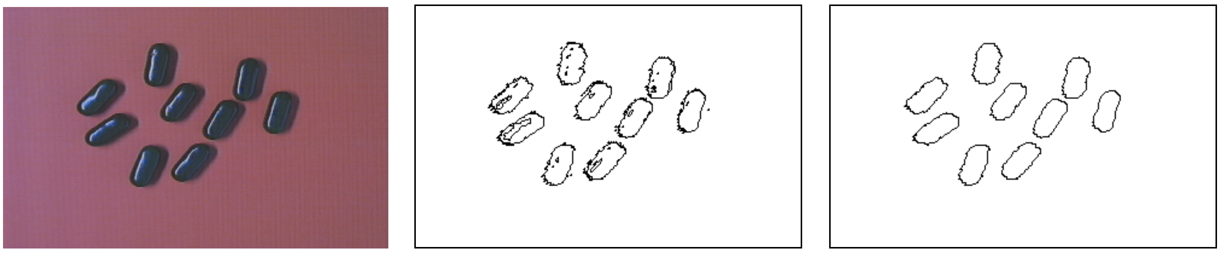


Fig.3 Influence of pre-processing (median filtering) on the segmentation results: (a) original colour image, (b) region boundary map for the original image (325 regions), (c) colour image after median filtering, (d) region boundary map for the HS-criterion for the filtered image (168 regions).



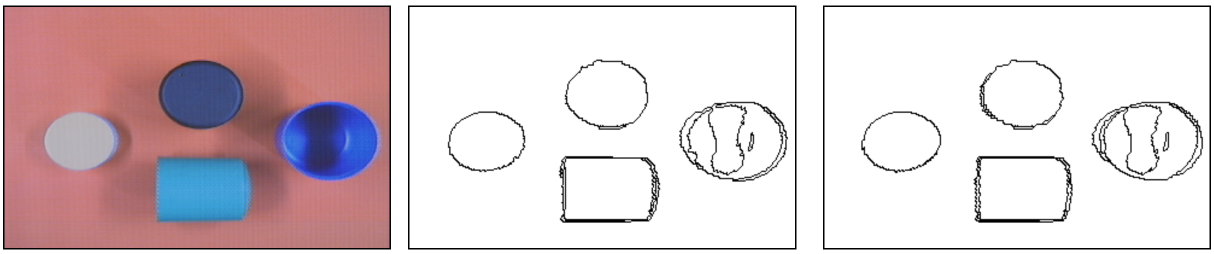
(a) (b) (c)

Fig.4 Avoidance of oversegmentation by using the region merging procedure: (a) original colour image, (b) region boundary map for the HS-criterion, d=0,08, (c) region boundary map for the HS-criterion after merging of regions equal in size or smaller than 25 pixels.

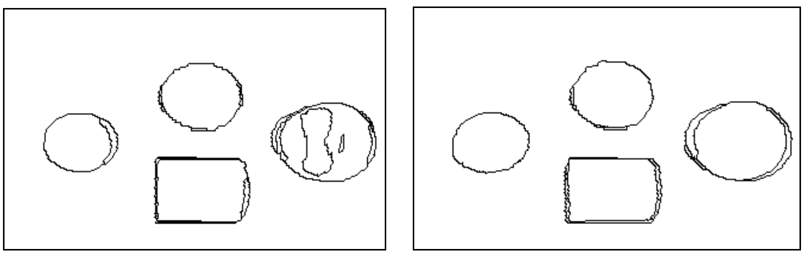


(a) (b) (c)

Fig.5 Removing small highlights from objects by using the region merging procedure: (a) original colour image, (b) region boundary map for the HS-criterion, d=0,15, (c) region boundary map for the HS-criterion after merging of regions equal in size or smaller than 150 pixels.



(a) (b) (c)



(d) (e)

Fig.6. Segmentation results for the HS-criterion and after merging of regions equal in size or smaller than 25 pixels: (a) "classical" version of RGB/IHS transformation, (b) Bajon's transformation, (c) HSV model, (d) HLS model.