COLOR SEGMENTATION ALGORITHM USING AN HLS TRANSFORMATION

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Abstract.
A new segmentation procedure for color images is detailed in this article. The segmentation still ends with the watershed function, but the whole series of pre-treatments applied to the color images is of interest. After a HLS transformation of the images, a color reduction is applied, followed by a median filtering. The gradient is then constructed from this resulting image. After this step, two different ways to obtain the boundaries are proposed: either a hierarchical segmentation or a simple watershed line followed by a merging of the bassins according to the color of their minima. All these steps are detailed in the following and the results obtained on test images are discussed.

Key words: Color segmentation, HLS space, Color reduction

1. Introduction

Color images are nowadays materials when dealing with image processing. But, if grey level treatments are numerous and well-known, color image processing is not so developped. In particular, color segmentation is at its beginning. This method presents an algorithm of color segmentation, based on mathematical morphology.

The segmentation produced by this algorithm does not allow to keep the details of the color images. The aim of our algorithm is to obtain the main regions of the image. Such an algorithm could be used in multimedia problems, for example indexation, or, in general, in any application which does not require small details.

As most of morphological segmentation algorithms, it requires a filtering step, before a gradient and a watershed building. But, before any filtering, two pre-treatments are applied to the color images. The first one is based on the color space HLS, and it will be called the HLS transformation, in the following. This pre-treatment is followed by a color reduction, and finally by a median filtering. Except the HLS transformation, which is rather new, the novelty of this algorithm lies in the ordering of these steps. Besides its simplicity, the resulting algorithm presents the advantage of enhancing the main regions of the image.

Each step of the color segmentation is described in the following, and some results are presented on different color images.

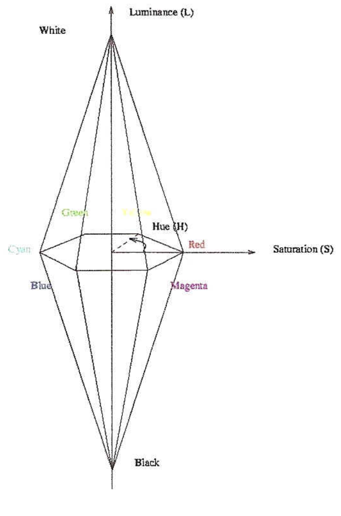


Fig. 1. HLS color space.

2. Segmentation steps

2.1. HLS TRANSFORMATION

Before any description of the HLS transformation, a few reminders of the HLS color space are needed. The three components of the HLS space are respectively the Hue, Luminance and Saturation. The Hue and Saturation components contain the whole color information. Among the Saturation and the Hue components, only the Hue really gives an information of the color domain of a pixel. According to the Hue component, one knows if a pixel is blue, yellow or green ... With a constant Hue, blue for example, different saturation values produce different pixels in the same color domain (with the same hue), from light to dark blue. The HLS space is illustrated in the figure 1. The vertical axis is the Luminance; the horizontal angle represents the Hue and, for a given angle, the radius is the Saturation.

The equations allowing to pass from the RGB color space to the HLS color space will not be detailed in this article. For a description, one should refer to [6].

The HLS transformation is a simple transformation which allows to split the color information from the luminance information. A first transformation was defined as follows:

$$\begin{aligned} \text{HLSTransformation} : \text{HLS} &\longrightarrow \text{HLS} \\ (h,l,s) &\longrightarrow (h',l',s') = (h,128,255) \end{aligned} \qquad (1)$$

This simple transformation only keeps the Hue information of the images. Because of the HLS space representation, this transformation presents the drawback of producing more or less arbitrary hue values for pixels with small saturation values.

These pixels do not really have any representative hue value, but a grey level. As their saturation value is small, small angle variations lead to critical hue variations. This is the reason why the sky appears green and yellow more than blue, in the HLS transformation (see figure 2, part *b*).

a) Original image

b) HLS transformed image

c) HLS transformed image ($s_0 = 10$)

d) HLS transformed image ($s_0 = 30$)

Fig. 2. Examples of HLS transformations. The HLS transformation of the original image (a) is successively presented for different thresholds: $s_0 = 0$, $s_0 = 10$ and $s_0 = 30$.

Another HLS transformation is then introduced to take into account those pixels whose color is not significant enough. Two different classes of pixels are considered, according to their saturation value. When the saturation is small enough (less than a threshold s_0), the pixel saturation and hue become zero, whereas the luminance is kept unchanged. For pixels with a high saturation value, the previous HLS transformation is applied.

This new HLS transformation, called *enhanced HLS transformation*, is then:

Enhanced HLS Transformation: HLS $\longrightarrow$ HLS

$$(h, l, s) \longrightarrow (h', l', s') = \begin{cases} (h, 128, 255) & \text{if } s \geq s_0 \\ (0, l, 0) & \text{if } s < s_0 \end{cases} \quad (2)$$

For different saturation values, the image colors will be transformed either into the nearest grey level, or into the hue only. These changes are illustrated in figure

2, for three different values of s_0: 0, 10 and 30 (the saturation range goes from 0 to 255). One should notice that, when s_0 is increasing, the sky is transformed in grey, and the background trees appear. For $s_0 = 30$, the transformed image contains only the main regions, which are sufficient for the segmentation.

Besides providing initial images for the color segmentation, the enhanced HLS transformation allows to distinguish objects according to their *spectral response* (the hue histogram of the image). For example, the sky and the vegetation have different hues; a simple threshold on the HLS transformation will then separate the sky regions from the vegetation regions. This is also a way to detect people, by analysing the spectral response of the skin. In fact, no matter the original color of the people skin is (white, yellow, black ...), the spectral response will be the same, between red and yellow. This is also illustrated in figure 3.

2.2. Color reduction

After the HLS transformation of the image, another pre-treatment is carried out. The aim of the color segmentation is still to produce the main color regions; with this goal, a drastic color reduction (up to 16) will simplify the image without reducing the information. The reduced HLS image is illustrated in figure 5. From this step, the colors shown on the image have no more significance, they are only labels of the remaining colors. This transformation will obviously not penalize the segmentation.

2.3. Median filtering

Finally, a last filtering (as usual in morphological segmentation) is needed to prepare the image. Three different filters were tested. The first two were morphological filters, an Alternate Sequential Filter and a Filter by Reconstruction. For a definition of these two morphological filters, one should refer to [5, 3]. These two filters were applied on each of the three components of the color image separetely, and the result image was obtained by recombining the three transformed components. This had the major drawback of introducing new colors into the image, which has the inverse effect of the color reduction. Moreover, these new colors do not have any meaning; they do not correspond to any image regions.

Besides, the alternate sequential filter and the filter by reconstruction do not provide a good filtering of the image, as it can be seen in figure 4. The first one modifies the region boundaries, and the second introduces pointillism, which will further produce over-segmentation.

These are the reasons why the filter which is used in this segmentation is a vectorial median filter. In the grey level case, a median filter acts on pixels according to their grey level order. As for color images, no total order can be defined on the colors, which are three-dimensional vectors. The vector median filter replaces then a pixel color by the color, which is at the minimum distance of all its neighbour colors. This is in fact a pseudo-median filter, but it treats the three components together and does not introduce new colors. Furthermore, the result contains no pointillism and the boundaries are still relevant (see figure 5, part *d*). To get more information on such a filter, one can refer to [1].

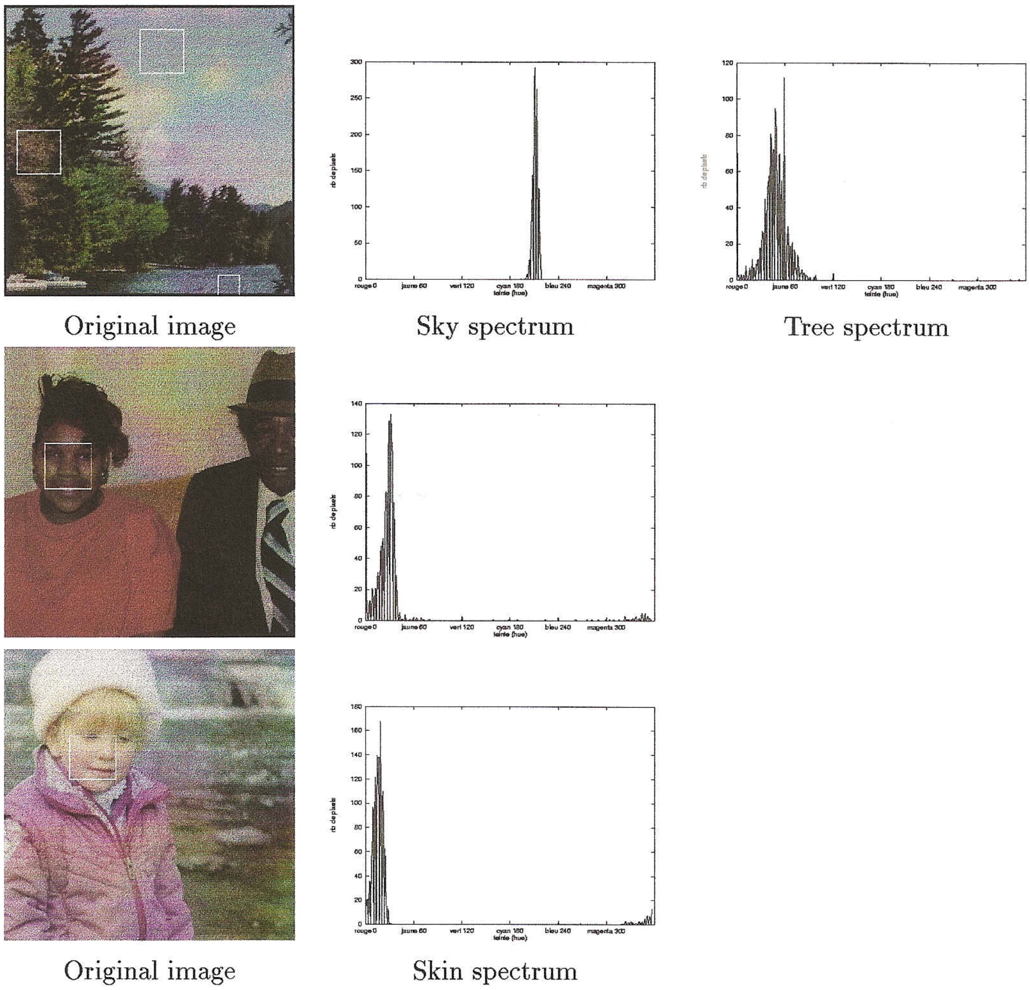
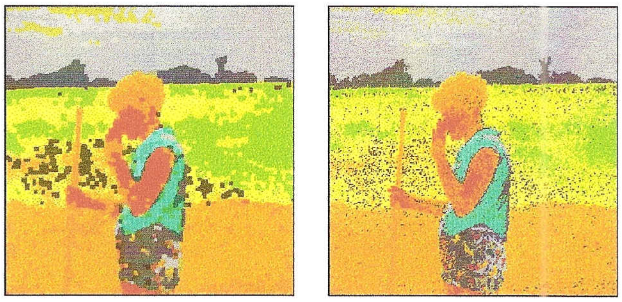


Fig. 3. Study of the spectral response of different regions.

2.4. Gradient

The gradient is the usual morphological gradient, but as the working image is a color image, one has to build the gradient from the three components again. We chose to construct the gradient separately on each of them, the resulting gradient is then obtained by adding these three gradients. Adding the three gradients allows to enhance the real boundaries which exist in each component, compared to boundaries which are present in one component only, as a suppremum of the three gradients would have led. These last boundaries do not represent real color differences.

The gradient step is shown in figure 5, part *e*.



Alternate sequential filter   Filter by reconstruction

Fig. 4. Morphological filters applied on the reduced color image.

2.5. Segmentation

In order to obtain the boundaries of the main regions of the image, two different segmentation algorithms were studied. The first algorithm is detailed in [2, 4, ?]; it consists in a hierarchical segmentation, still based on the watershed. As for the second algorithm, a watershed is also build and a merging of the regions, according to the color of their minima, is processed. These two algorihms are successively described in the following.

2.5.1. *Hierarchical segmentation*

The hierarchical segmentation allows to obtain iteratively less detailed segmentations. It starts from the image watershed, which is usually quite over-segmented, and it erases successive boundaries, which are found less significant. At each step, the gradient is modified, and the boundaries which are suppressed correspond to smaller values of the modified gradient. References on the hierarchical segmentation were already given above, but here are a brief description of a hierarchical segmentation algorithm, also called waterfall algorithm.

First the usual gradient of the HLS transformed image is computed. From this gradient, a first watershed is build (see figure 5, part *f*). The gradient modification is then done as follows. One constructs an image, which is at 255 into the bassins, and which has the gradient values on the watershed lines. The modified gradient image is the reconstruction by erosion of the original gradient from this new image. A new watershed is then built from the modified gradient. This operation could be repeated until no more boundaries are left. At each step, the less relevant boundaries, according to the new gradient, are suppressed.

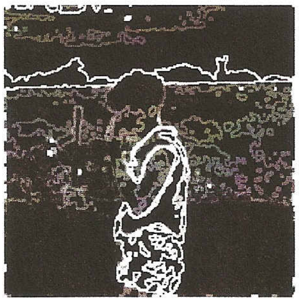
For the kind of color images that were tested, only one step of hierarchical segmentation was necessary. As for the execution time, this algorithm needs then two watershed constructions, and the preparation of the new gradient. This is quite equivalent to a simple watershed segmentation. The result are illustrated in figure 5, part *g*. It should be noticed that all main regions are kept in the final segmentation.

a) Original image

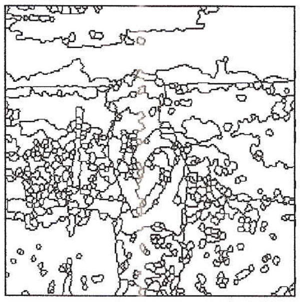
b) HLS transformation

c) 16 color image

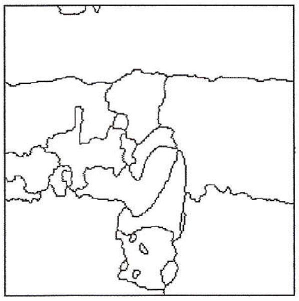
d) Median filtering



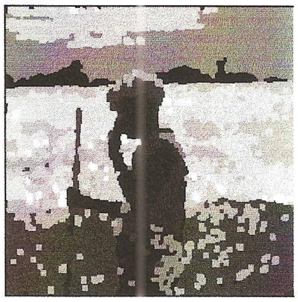
e) Gradient (sum of the 3 components)



f) Initial watershed



g) Hierarchical segmentation



h) Merging of the bassins

Fig. 5. Different steps of the color segmentation.

2.5.2. *Merging of the bassins*
This algorithm begins with a classical watershed obtained from the gradient, each bassin corresponding to a minimum of the gradient. The resulting image is generally over-segmented. To each minimum of the gradient, one can associate the corresponding color in the reduced image. One merges the bassins whose minima have the same color. The shared boundary is suppressed. This algorithm is rather simple and the result (presented in figure 5, part *h*) is correct: the main regions and their boundaries are well restored. When comparing with the hierarchical segmentation, the results are quite equivalent; as for the execution time, it is also quite the same, with a small advantage for the merging algorithm.

3. Conclusion

In this article, a new color segmentation algorithm was presented. This algorithm contains uses several pre-treatments, in order to simplify the color image, before the segmentation. These pre-treatments reduce dramatically the color information (number of colors, small details, etc), without modifying the important region boundaries. The results on test images prove the validity of the algorithm, for the foreseen applications. These applications can be mainly found in the multimedia domain. One may consider to address such problems as indexing images or sequences, finding people in images, sorting out outside or inside shots, etc. More generally, such a segmentation could be of a great interest for the new image compression standard MPEG7.

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