Evolution of Contour using Deformable Model in RGB, HSV and LAB Color Spaces

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Abstract: The way humans describe and interpret the color corresponds more closely to HSV and LAB color spaces. In this paper, we have analyzed the properties of HSV (Hue, Saturation and Value) and LAB color models with emphasis on practical interpretation of the colored objects by humans. We segment the images using deformable model (Chan-Vese) based on curve evolution, Mumford-Shah functional and level set. Features are extracted using either saturation or intensity as the dominant property in HSV color space. Color segmentation is performed in LAB color space. The results have been compared on the basis of segmented area and execution time with those generated using RGB color space.

Keywords: Active contours, energy minimization, segmentation, energy function, deformable models.

1. INTRODUCTION

Image segmentation is the first step in image analysis. Segmentation procedures partition an image into its constituent parts or objects. It refers to the process of partitioning a digital image into multiple segments i.e. set of pixels, pixels in a region are similar according to some homogeneity criteria such as colour, intensity or texture, so as to locate and identify objects and boundaries in an image [1]. In general, autonomous segmentation is one of the most difficult tasks in digital image processing. Using a PDE based method & solving the PDE equation by a numerical scheme one can segment the image. Image segmentation based on PDEs is mainly carried out by active contour model or snakes. This method was first introduced by Kass et al in 1987 [2]. Kass developed this method to find familiar objects in presence of noise and other ambiguities. The central idea of snake is transforming a segmentation problem into a PDE framework. The name deformable models or snakes first appeared in work by Terzopoulos and his collaborators, the ideas of deforming an elastic template date back much further to the work of Fischler and Elschlager's spring loaded template(1973) and Widrow's rubber mask technique(1973). Active contours or snakes are computer generated curves [3] that move within the image to find object boundaries under the influence of forces of curve and image itself. Active contours detect the objects in a given image, based on techniques of curve evolution, Mumford–Shah functional for segmentation and level sets. This model can detect objects whose boundaries are not necessarily defined by gradient. Active contours without edges, Active contour without edges for vector image, Active contours with multi-phases. Each one is having different speed and quality. These methods could be implemented on gray scale images as well as on coloured images. The vector-valued C–V model can also be used on color images. By dividing the image into red, green, and blue (RGB) channels, one can detect objects normally undetectable when the color image is transformed to a scalar intensity image [4]. Color is the brain’s reaction to a specific visual stimulus. The CIE system allows the measurement of color according to the characteristics of human vision. A CIE specification system enables a color to match with another, and can be used to predict visual differences between colors. It does not tell about the appearance of the color as it is influenced by the type of lighting, geometry of color surface and the characteristics of surrounding colors that are in visual field. The difference between colour measurement and colour appearance can result in problems when trying to match colours between different devices, for example between a hard copy output and an image on a soft display. The solution is to use such an appearance space that enables us to predict what a colour will look like when viewed by a (typical) observer in a variety of conditions [5]. Using such a system it is possible to get accurate colour reproduction between soft display and hard copy at the expense of computational complexity. In section II of this paper, Chan-Vese technique of active contours has been described, section III describes the various color spaces such as RGB, HSV and LAB and their transformations, and the rest of the paper describes the comparison of the segmentation on different types of images in various color spaces.

2. IMAGE SEGMENTATION

One can segment the image using a PDE based method & solving the PDE equation by a numerical scheme. Image segmentation based on PDEs is mainly carried out by active contour model or snakes. This method was first introduced by Kass et al in 1987 [2]. The original idea by Kass, Witkin and Terzopoulos [3] is to initialize a curve in an image and let this curve move until it adapts to the contour of a searched object. The motion of the curve is driven by the image itself. The driving force is obtained by defining a potential in the image that shall be small near objects contours. The objective is to minimize an energy which can be seen as a particular case of the minimal partition problem. In the level set formulation, the problem becomes a “mean-curvature flow”-like
evolving the active contour, which will stop on the desired boundary. Chan-Vese Energy function [3] is given by the following equation 1

$$E = \mu_0 (\Phi(x,y) - 1) + \int |\nabla \Phi|^2 dA$$

(1)

- $E$ = Energy of the curve + energy of the image.
- $\mu_0$ = given image.
- $C_0$ = the boundary of the object to be detected.
- $C$ = any closed curve.
- $C_1$ = average intensity of the image inside C.
- $C_2$ = average intensity of the image outside C.

$\mu$, $\nu$, $\lambda_1$, $\lambda_2$ are the parameters whose values lie between 0 and 1[5]. The objective is to minimize the $E$, when E will be minimum $C= C_0$ and image will be segmented. In [5] Chan-Vese approach involves geometric active contour model (based upon Mumford – Shah Functional [5]). The model begins with a contour in the image plane defining an initial segmentation and then contour is evolved according to evolution equation. The Basis of Chan-Vese algorithm is a “Fitting Energy Functional”. The goal of algorithm is to minimize this fitting energy for a given image and corresponding $\Phi$ will define segmentation.

2.1 Level Set Function

Chan Vese algorithm evolves this contour via a level set method [5]. The function $\Phi (i,j)$ (the level set function where(i, j) are co-ordinates in the image and t is time).

The segmentation is given by two regions $\{\Phi >0\}$ and $\{\Phi<0\}$. The boundary of the shape is then the zero level set as in Figure 1. The minimization problem requires minimizing over all set boundaries $C$. This is accomplished by applying the level set technique introduced by Osher and Sethian [6]. Instead of manipulating $C$ explicitly, it is represented as the zero-crossing of a level set function $\phi$ by the relationship

$$C = \{x: \phi(x) = 0\}$$

Furthermore, the inside and outside of $C$ are distinguished by the sign of $\phi$. As an example,

$$\phi(x) = -\left(x^2 + y^2\right)^{1/2}$$

is a level set function for a circle of radius $r$, where $x=x_1$, $y=x_2$.

Figure 2 Level set function for a circle of radius $r$.

The Chan-Vese energy equation can be rewritten[3] in terms of the level set function $\phi$ as equation 2

$$E = \int \left[\left|\nabla \phi \right|^2 + \mu_0 \delta (\phi) \right] dA + \int \left[\mu \phi^2 - \nu \lambda_1 |\nabla \phi|^2 - \lambda_2 \phi \right] dA$$

(2)

where $H$ denotes the Heaviside function and $\delta$ the Dirac mass.

Basic steps of Chan-Vese algorithm are:

5. Initialize $\Phi$, the initial curve in the image.
6. Compute $C_1$ and $C_2$, the average intensities inside the curve and outside of it.
7. Calculate the energy function from equation (1).
8. Check whether the solution is stationary, energy is minimum. If not, and repeat [3].

Chan-Vese implemented active contours to find segmentation of the image through various methods: Active contours without edges, Active contour without edges for vector images, Active contours with multi-phases. Each one is having different speed and quality. These methods could be implemented on gray scale images as well as on coloured images. Image without noise can be treated as a gray image. Otherwise it can be treated as a vector image for better de-noising ability indicating more calculations and complexity. Chan–Vese has also been extended for segmentation based on Gabor texture cues [13]. A disadvantage of Chan–Vese is that it only provides segmentation into two phases. Extensions of Chan–Vese have been developed for nested segmentation curves [14] and multiphase segmentation [12], [15]. Tsai, Yezzi, and Willsky [11] developed a general level set curve evolution framework similar to Chan–Vese for Mumford–Shah segmentation and simultaneous segmentation, denoising, and inpainting. Chan-Vese work is limited to gray-scale images and colored images in RGB color space only. We have analysed the properties of two other color models HSV.
(Hue, Saturation and Value) and LAB color model and found that they have some specific properties which can assist in better evolution of the contour for some specific type of images.

3. COLOR TRANSFORMATION

One reason for using other color spaces than RGB is that experiments have shown that no single color space is best and it seems to depend somewhat on the content of the image. Different colour spaces are better for different applications, for example some equipment has limiting factors that dictate the size and type of colour space that can be used. Some colour spaces are perceptually linear, i.e. a 10 unit change in stimulus will produce the same change in perception wherever it is applied. Many colour spaces, particularly in computer graphics, are not linear in this way.

3.1 RGB (Red Green Blue)

In RGB color model, the image is represented as a three component image, one for each primary color. These three components (Red, Green and Blue) or three images combine on screen to produce a composite color image. Figure 3(a) represents the safe color cube whose entire surface is covered by 216 different colors[1].The three axis of the RGB safe space cube corresponding to red, green and blue. The bottom corner, when red = green = blue = 0 is black, while the opposite top corner, where red = green = blue = 255 (for an 8 bit per channel display system), is white. RGB is frequently used in most computer applications since no transform is required to display information on the screen. RGB is most commonly used in hardware-oriented models like color monitors and a broad class of color video cameras. RGB is easy to implement but non-linear with visual perception. It is device dependent and specification of colours is semi-intuitive.

3.2 HSV (Hue Saturation Value)

HSV color space has a three dimensional representation in the form of hexacone, where the central vertical axis represents the intensity and the locus of the color points lie on the planes perpendicular to the axis[7]. HSV colour space is a deformation of an RGB color cube. If you imagine the RGB cube tipped cube onto the black corner then the line through the cube from black to white defines the lightness axis. The color is then defined as a position on a circular plane around the lightness axis. Hue is the angle from a nominal point around the circle to the colour while saturation is the radius from the central lightness axis to the colour. Hue is defined as an angle in the range [0,2π] relative to the Red axis with red at angle 0, green at 2π/3, blue at 4π/3 and red again at 2π. Saturation is the depth or purity of the color and is measured as a radial distance from the central axis with value between 0 at the centre to 1 at the outer surface. For S=0, as one moves higher along the Intensity axis, one goes from Black to White through various shades of gray [7]. One of the advantages of this color model is the skin color searching model, this model seeks for the human skin pigment and segments this color component accordingly, by using some range of predefined values for each of the HSV color components [8]. We can have better segmentation results on images which involves skin color.

3.2.1 RGB to HSV Transformation

An image in RGB color format can be transformed to HSV using the following equations [1] for each RGB pixel

\[
H = \begin{cases} 
\theta & \text{if } B \leq G \\
(360 - \theta) & \text{if } B > G 
\end{cases}
\]

With \( \theta = \cos^{-1} \left( \frac{-2GB + B + G + R}{2GB + B + G - R} \right) \)

The saturation component is given by

\[
S = 1 - \frac{3}{L+\frac{2}{a+b+c}} \ln a(G,B) \]

Finally, the intensity component is given by the following equation

\[
I = \frac{R + G + B}{3}
\]

3.3 LAB

A Lab color space is a color-opponent space with dimension L for lightness and a and b for the color-opponent dimensions, based on nonlinearly compressed CIE XYZ color space coordinates. Unlike the RGB and CMYK color models, Lab color is designed to approximate human vision. It aspires to perceptual uniformity, and its L component closely matches human perception of lightness. It can thus be used to make accurate color balance corrections by modifying the a and b components, or to adjust the lightness contrast using the L component [9]. The RGB color model is used to obtain the output of physical devices rather than human visual perception. Color is represented in many different color systems. The choice of the color space can be a very important decision which can influence the segmentation result. We study several color spaces in order to select the appropriate one. The color space has to be perceptually uniform to achieve segmentation so that it can be used to express regions homogeneity into a given image. Perceptually uniform means that a change of the same amount in a color value should produce a change of about the same visual importance[10]. This study revealed that the RGB color space has some drawbacks: in particular, the strong correlation between the three components R, G, B and the redundancies of many colors. The study showed also that in the HSV and HSL color spaces, when the luminance and/or saturation tend to 0, the value of the
component "Hue" loses its importance. These spaces do not correct the lack of homogeneity of the RGB color space and are dependent on the system that produces color. In the other hand, Lab color space, proposed by the CIE (The International Commission on Illumination - abbreviated as CIE from its French title Commission Internationale de l’Eclairage) is known as a perceptually uniform color spaces. Based on the previous study on color spaces, we opted for the CIE-LAB color space. In Lab color space, the \( L \) component represents the luminance; \( a \) component presents the colors between the red and the green; \( b \) component presents the colors between the yellow and the blue. Lab model is a three-dimensional model; it can only be represented properly in a three-dimensional space.

### 3.3.1 RGB to LAB Transformation

There are no simple formulas for conversion between RGB or values and \( L^*a^*b^* \), because the RGB color model is device dependent. The RGB or CMYK values first need to be transformed to a specific absolute color space, such as XYZ. This adjustment will be device dependent, but the resulting data from the transform will be device independent, allowing data to be transformed to the CIE 1931 color space and then transformed into \( L^*a^*b^* \).

4. **THE PROPOSED METHODOLOGY**

First of all the input colored image is taken, then the image is mapped to the HSV and LAB color space by using the transformations. The initial input image is in RGB color space by default. We have used the intensity factor of RGB images to run the CHAN-VESE segmentation algorithm. In case of HSV color space we have used both the saturation and value property as the desired color space, the next step is to initialize the level set function or contour in the image and then the values of CHAN-VESE parameters are set as per the requirement of the segmentation. We calculate the internal and external energy as per the equation and let the curve to evolve till the energy is minimized or more precisely let the level set function to evolve till convergence. At the point of convergence we get the segmented image.

![Figure 3(a)-(c) Representation of RGB, HSV and Lab color spaces.](image)

5. **RESULTS AND ANALYSIS**

We have tested the algorithm on a large number of natural scene images. In this paper we demonstrate results that represent our findings from these experiments.

5.1 RGB v/s HSV Segmentation

In figures 5(a)-(c), we show three images, their HSV-based segmentation results and RGB-based segmentation results. For RGB, we consider the intensity factor to perform the segmentation and for HSV we consider the saturation and value components to perform the segmentation. Although exact segmentation of unconstrained color images is still a difficult problem, we see that the object boundaries can be identified in a way more similar to human perception of the same. The RGB features, on the other hand, fail to determine the color and intensity. We have applied CHAN-VESE algorithm on hand gesture images and infected tongue images using the \( S \) and \( V \) components of the HSV images because the most striking feature of HSV is skin color extraction. We have also applied segmentation on noisy images in HSV color space and that evolution of the contour is better and fast in HSV color space than RGB. As shown in figure 4(a)-(c), the original image of infected tongue, hand gesture and a noisy image are taken and segmentation is performed in RGB and HSV color space. The results show better contour evolution in case of boundary detection of infected region of tongue in HSV using saturation component and in case of RGB, the infected area is not properly detected. In the second case hand gesture is taken and the outline is segmented using value component in HSV and intensity in RGB, which is found to be better in case of HSV. In the noisy image the
segmentation in HSV space is almost complete in a few iterations whereas in RGB segmentation, it has just
started. We have kept the number of iterations fixed and calculated the segmented area ratio and time of execution
in different color spaces. Table 1 shows the findings of these parameters.

The time of execution in HSV color space is less as compared to RGB while the segmented area ratio is less but the required region is properly segmented in HSV space.

5.2 RGB vs LAB Segmentation
In figures 6(a)-(c), we show two images, their LAB-based segmentation results and RGB-based segmentation results.

For RGB, we consider the intensity factor to perform the segmentation and for LAB we consider the luminance and chrominance components to perform the segmentation. LAB color space is device independent and is efficient in extracting small color differences. The RGB features, on the other hand, fail to determine the color and intensity. We have applied active contour segmentation on colourful images and found that the contour evolution is much better in LAB color space than RGB.

Table 2 shows that the segmented area ratio is more in case of LAB than of RGB and there is a little time difference also in the execution of fixed number of iterations. As we can see in figure 5(a)-(c) the contour evolution is much faster and segmentation is more detailed in LAB color space than RGB as LAB model is more close to the way humans perceive the colors.

Table 1:

<table>
<thead>
<tr>
<th>$\lambda_1$</th>
<th>$\lambda_2$</th>
<th>$\mu$</th>
<th>$\upsilon$</th>
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<tbody>
<tr>
<td>1</td>
<td>1.0</td>
<td>0.03</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
<td>0.03</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>0.03</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2: Comparative analysis of HSV and RGB color space with $\lambda_1=1.0$, $\lambda_2=3.0$, $\mu=255*255*0.05$, $\upsilon=0$. 
Table 2: Comparative analysis of LAB and RGB color spaces for different images with the values of $\lambda_1=1.0$, $\lambda_2=5.0$, $\mu=255*255*0.03$, $\upsilon=0$

<table>
<thead>
<tr>
<th>No</th>
<th>Image</th>
<th>LAB Segmented Area Rate</th>
<th>Time of Execution (seconds)</th>
<th>RGB Segmented Area Rate</th>
<th>Time of Execution (seconds)</th>
<th>ITERATIONS</th>
</tr>
</thead>
<tbody>
<tr>
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<td>59.644239</td>
<td>0.365086</td>
<td>54.216599</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>COLORBIRD</td>
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<td>316.086935</td>
<td>0.259976</td>
<td>217.916494</td>
<td>900</td>
</tr>
</tbody>
</table>

Figure 7 Comparison of RGB and HSV with reference to Time of Execution of segmentation on Hand Gesture image.

Figure 8 Comparison of RGB and LAB with reference to Segmented Area Ratio on Bird image.

6. CONCLUSION

We have analyzed the properties of RGB, HSV and LAB color models and performed the Chan-Vese segmentation on real and synthetic images. The segmented images in HSV and LAB color spaces are compared with reference to the segmented area ratio and time of execution with those in RGB space. The evolution of contour is faster in HSV and better segmentation results are observed in LAB color space.

REFERENCES