Enhancement of medical images in HSI color space

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Abstract. In this paper we use the HSI color space as an alternative to RGB space. The HSI space considers the image as a combination of the components: hue, saturation and intensity. In this paper we propose to design a chromatic filter in order to obtain improvements in the enhancement of medical images. In image processing systems it is usual specify colors in a form compatible with the hardware used. The RGB color model, where is computationally convenient, is not very useful in the specification and color recognition. The human being does not recognize a color by having an amount of red, green or blue components, but uses attributes perceptual of hue, saturation and intensity. The chromatics models HSI, HLS, HSV, and its variants, encodes the color with the above attributes and are defined as intuitive spaces.

1. Introduction
The color image processing is motivated by two important factors, by a similarity to human vision, fully chromatic, and second, by the increasing of the information that the chromaticity contributes to the analysis of images.

The digital image processing techniques proposed have been developed for binary images or gray levels [1-2]. For many years, this limitation has been imposed by the hardware. This is because the computational cost of the color processing image algorithms is very high, making it necessary to reduce the visual information to a unique two-dimensional map. While these images contains information of scenes captured, the reduced to two dimensions of a visual environment causes the loss of information to discriminate certain objects in it. This is because the chromaticity of the forms is not reflected and the luminance is homogeneous in this type of map. The growth of computing power, the storage capacity and the reduced costs of capture systems and printing images have made that the image acquisition is made in color, and that further analysis and processing is carried out in tridimensional maps.

Color spaces provide a method for specifying, ordering and manipulating colors. Usually it is determined by a base of n vectors whose linear combinations generate all elements of the space. There are numerous color spaces among which we can mention the gray scale, which is one-dimensional space, the planes RG, GB and BR, which are two-dimensional spaces and the spaces RGB (Red, Green and Blue), HSV (Hue, Saturation , Value), HSI (Hue, Saturation, Intensity) and YIQ, which are three-dimensional spaces [3-4].

In the RGB model, the color is specified by red, green and blue amounts. In this model, a digital image consists of three planes of independent images, each of which stores the values of red, green and blue. This model has serious disadvantage when you want to perform different types of processing of the images such as enhancement, segmentation or classification [5]. To eliminate or reduce these...
limitations be have created models that separate the color information of the lighting information such as the HSI space. As in the RGB space, a digital image in the HSI space consists of three matrices of $m \times n$ dimension, which saves the values of hue, saturation and intensity. Thus, each pixel of an image represented in this space has three data: hue and saturation which provide information of color, and intensity which describes the brightness.

The application of alternative color models to the medical image processing has as main objective improve the performance of algorithms for enhancement, segmentation and classification. Thus, it provides tools to the specialist to reduce the error in the performance of different types of diagnostic.

2. Color models or color spaces

Due to the nature of the human eye and due to the tri-chromatic theory, all colors that humans can recognize in an image are a combination of so-called primary colors red (R), green (G) and blue (B). The goal of a color model is to facilitate the specification of colors in a standardized way.

A color model is the specification of three-dimensional coordinate system and of one subspace of this system in which each color is represented by a unique point. The choice of a suitable space for color representation remains a challenge for scientists researching color image processing.

2.1. RGB Color Model

In RGB space, color is specified through red, green and blue amounts, forming in 3D space the cube depicted in figure 1. Each color is a point on the surface or inside this cube. The gray scale is located in the diagonal that joins the white color with black color, i.e. the diagonal joining the points (255,255,255) and (0,0,0). The range of each coordinate or chromatic RGB component is, usually, a value belonging to the interval [0,255]. Images in the RGB color model consist of three planes of independent images, each corresponding to a primary color. The individual processing of these three planes allows extract shapes and significant details of the images. However, there are times when this model is not suitable for image processing. Between the disadvantages of this model stands out the non-uniformity, i.e., is not possible to evaluate the observed difference between colors with a measure of distance from the primaries colors R, G and B.

![Figure 1. RGB model representation.](image)

2.2. HSI color model

The HSI model defines a color model in terms of its components. This space has the ability to separate the intensity of the intrinsic information of color, which refers to the hue and saturation. This model is suitable for processing images that present lighting changes this is due to the fact that the colors of the environment are distinguishable from each other through the hue component.

The most common way of representing the HSI model is a double cone, as shown in figure 2. The center of the double cone is a circumference divided into equal size angles. Therefore, the value of the
hue component describes the color by its wavelength, and takes values between 0 and 2\pi, with 0 representing the red, 2\pi representing the yellow and 4\pi representing the green. The distance from the center to the outside of the circumference represents the color saturation and takes values between 0 and 1. Saturation refers to the mix of color with white light. Finally, the axis through the two cones corresponds to the intensity component. This will have a value between 0 (black) and 1 (white) and indicates the amount of light present in a color. Removing a small circumference of the figure formed by two cones, colors close to an intensity of 1 are lighter than those close to zero. When the saturation component is close to 0, colors only reflect a change between black and white. When this component is close to 1, the color will reflect the true value represented by the hue.

Figure 2. HSI model representation.
The letters R, Y, G, C, B, M refer to = Red, Yellow, Green, Cyan, Blue and Magenta respectively.

2.3. RGB to HSI conversion

The spaces that represent the color in terms of hue, saturation and intensity, allow an intuitive description of the colors. The transformation of RGB space to HSI space is the conversion of a cartesian coordinate system to another in cylindrical coordinates, where the color is specified in terms of hue, saturation and intensity. A good representation of color must use norm or distance to make that the chromatic and achromatic components are independents. The equations that establish the change of coordinates between the components of both color spaces, using the semi-norm max-min, are given by:

\[
\begin{align*}
I &= 0.23R + 0.715G + 0.072B \\
S &= \max R,G,B - \min R,G,B \\
\theta &= \arccos \left( \frac{2R - G - B}{2 \sqrt{R^2 + G^2 + B^2 - RG + RB + GB}} \right) \\
H &= \frac{360}{\theta} \text{ if } B > G \\
&= \frac{360}{\theta} \text{ if } B \leq G
\end{align*}
\]

(1)

The following section presents the proposed method for intensity enhancement.
3. Proposed Method: Selective Chromatic filter

The proposed algorithm for the selective chromatic filter has the following steps:

• First we extract the color of interest of the original image using manual selection. The algorithm select the correspondent color code on the matrix H (a value between zero and one).

• Based on the selected color and allowing a range of tones above and below it (color band pass filter), a mask with the image pixels that are within that range is obtained.

• At last, this mask is applied to get darker the pixels which colors are outside the filter passband in the intensity component.

To compare the quality of filtering in HSI space with respect to RGB space, we performed the same filtering, but now on each matrix of RGB space, red, green and blue. The final mask results the combination of a logic and function applied to the individual masks obtained. This chromatic filtering is more restrictive in RGB space because there is a high degree of correlation between the RGB components.

Figure 3 (a) shows a synthetic image that reproduces the color palette on a ring, while the inner triangle shows the variation of the intensity. Figure 3 (b) and (d) shows the results of applying the chromatic filter in the HSI space for two different tones, while figure (c) and (e) show the counterpart to the RGB space. It may be noted a further restriction of colors leaked in the latter space, being the passband of the filters used in both equivalents cases.

Figure 3. Processing a synthetic image. (a) Original image. (b) Enhancing the yellow component in the HSI space. (c) Enhancing the yellow component in the RGB space. (d) Enhancing the cyan component in the HSI space. (e) Enhancing the cyan component in the RGB space.
4. Some Bioengineering Applications

This section shows different chromatic filter applications implemented in HSI space in some medical images. To compare the results, we include the same segmented images in RGB space, using a similar chromatic filtering. In these images we can observe light and dark areas, the first corresponds to a passband filter, while the last correspond to the band reject filter.

Figure 4 represents an electron micrograph image showing a nerve demyelination [6]. The region coloured in red is a section of an axon-transmitter of nerve impulses to other neurons-which has lost its myelin sheath. This is a disorder seen in multiple sclerosis disease. Figure 4 (a) shows the original image, figure 4 (b), (d) and (f) show the enhancement of the blue component, the red component and the green component respectively, using the chromatic filter on the HSI space. In figure 4 (c), (d) and (g) we observe the same images filtered in RGB space.

![Image of electron micrograph](image)

**Figure 4.** (a) Electron micrograph showing a nerve demyelination. (b) Enhancement of blue component in HSI space. (c) Enhancement of blue component in RGB space. (d) Enhancement of red component in HSI space. (e) Enhancement of red component in RGB space. (f) Enhancement of green component in HSI space. (g) Enhancing the green component in RGB space.
Figure 5 (a) corresponds to an endoscopy image with a Barrett's disease diagnose. This is a disease caused by reflux of gastric juices or intestinal content, which is rich in bilis, towards the esophagus. This occurs when the mechanisms existing in the gastroesophageal union for prevent it, fails [7-8]. Barrett's esophagus is considered precancerous.

To achieve a better diagnosis by observing this kind of lesion, in order to select more accurately the areas to biopsy, several techniques to enhance endoscopic images have been developped. These techniques are used in order to make a diagnosis more accurate, less intrusive. Figure 5 (b) shows the result of applying chromatic filter on the HSI space. The areas of interest where the specialist should take the biopsy were determined successfully. Figure 5 (c) shows the same segmented image in RGB space with very poor results.

Figure 5. (a) Barrett's Esophagus image. (b) Enhancement of the affected area in HSI space. (c) Enhancement of the affected area in RGB space.

At present, studies of human identification using molecular biology techniques can be performed automatically. In third world countries horizontal electrophoresis in agarose gels is still used. In the last case the DNA fragments amplified by PCR (Polymerase Chain Reaction) or multiplex monoplex reactions are separated by horizontal electrophoresis [9-10]. The results are obtained analyzing the length of DNA strands present in the sample and its concentration on molecular weight markers. Making this old process automatic is a big step until an automatic instrument can be afford. Figure 6 (a) shows an agarose gel produced by a process of electrophoresis. Figure 6 (b) shows how the application of the proposed filtering method to this kind of images. It can be observed the existence of two valid bands in the filtered image, optimizing the interpretation by the experts, whereas in figure 6 (c) that it is not possible because the bad results of the RGB filtering.
Figure 6. (a) Original image of agarose gel. (b) Enhancement of an agarose gel in HSI space. (c) Enhancement of an agarose gel in RGB space.

Figure 7 (a) shows an image of a brain scan with hypertensive encephalopathy in a woman of 23 years of age [11], which has suffered an acute arterial hypertension in association with cyclosporine. Figure 7 (b) shows the enhancement of areas of bright orange in HSI space and figure 7 (c) shows its counterpart in the RGB space.

Figure 7. (a) Image of a brain scan: Hypertensive encephalopathy. (b) Enhancing the orange area in HSI space. (b) Enhancing the orange area in RGB space.
5. Conclusions
Choosing a suitable color model is heavily dependent on the application and is the first step in the processing of medical images in color. Although the RGB model is best suited to display color images, the preliminary results obtained shows that this space is not suitable for analysis and processing imaging with a high degree of correlation between the components R, G and B. Furthermore, the distance between colors in this space does not represent color differences such as the human visual system perceives them. The HSI model have as key attribute the advantage of separating the intensity of the intrinsic color information, which is important when images are affected by changes in lighting. This paper proposed the HSI color space as an alternative to the RGB space and design a chromatic filter for improve medical image enhancement. It could be observed that in the HSI space is possible to integrate variations in lighting without compromising the classification significantly.

6. References