於色彩意像空間中進行室內影像之著色
COLORING OF INTERIOR IMAGES BASED ON COLOR-IMAGE-SCALE*

袁武雄　　沈毓銓　　許文星
Wu-Hsiung Yuan†, Yu-Chuan Shen† and Wen-Hsing Hsu†, ‡

國立清華大學　電機工程學系　視知覺實驗室
† Visual Perception Laboratory, Department of Electrical Engineering, National Tsing Hua University, Hsinchu, Taiwan 300, R.O.C.

中央研究院　資訊科學研究所
‡ Institute of Information Science, Academia Sinica, Taiwan, R.O.C.

E-mail: whhsu@mercury.ee.nthu.edu.tw, Fax: 035–715971, Tel: 035–710300

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摘要

著色在電腦繪圖的領域中是經常應用的一種輔助技巧，它的目的是要使影像結果更為生動逼眞。然而過去在色彩的選擇上，是由使用者依自己的喜好選取（ manual-based selection ），色彩間的協調因素幾乎都未考慮。本實驗室在這方面的研究，已發展出能定量評估色彩協調之特徵空間－色彩意像空間（ Color-Image-Scale ）。在本篇論文中，我們於色彩意像空間中，利用了統計圖指定（ Histogram Specification ）的觀念，提出了一個室內影像著色系統，能針對室內影像進行色彩協調的調變，其精神是類似於統計圖指定應用在灰階影像增強上的意義。其與過去傳統的著色技巧的差異之處在於，我們的系統提出了兩個新的想法，一是完全自動地針對室內影像進行著色美化，另外同時也考慮了整體色彩的協調程度。

關鍵字:
室內影像著色系統、色彩協調、色彩意像空間、統計圖指定、色彩協調之調變。

Abstract

Coloring is a frequently used technique in the field of computer graphics. However, the harmony of resultant colors had not yet been evaluated in the conventional algorithms. Previously, a 1D image scale of 'CHEERFUL-SILENT' has been constructed to quantitatively evaluate the color harmony of interior images. In this paper, combined with the evaluation of color-harmony, a coloring system is proposed based on the harmony principles described in the 1D color image scale. Our objective is to coloring the interior image according to the grade of human's pleasure/disgust. The procedure is that an interior image is first coded as a color linguistic distribution(CLD), representing mental color impression of the whole image. Furthermore, two types of histogram specification techniques are applied to adaptively modifying the coded CLD by proper references. Based on the resulted CLD, a resultant interior image can be reconstructed by a decoded procedure of color interpolation. The uniform color space of CIE1976(L*u*v*) is used to preserve the linearity of color additivity. Experimental results demonstrate that the proposed coloring system can obviously improve the mental impression on colors. Also, our potential and further developments are outlined.

Key Words: color harmony, color image scale, color linguistic distribution(CLD), histogram specification, color interpolation.

1 Introduction

Color makes us break away from monotony of black-and-white world . The stimulation to human vision organization via color perception generates responses of physiology and psychology. Conventional research of image processing are focused on physical characteristics of color and visual model of color perception. However, the harmony of colors also influences the aesthetic ability upon human beings.

Besides, each different color, in addition to its original name, might represent another linguistic meaning. For instance, when we saw 'redness', it not only means 'red', but also represents '*passion*','*vivacity*',....and so on. This is a psychological association of color. Therefore, many classifications such as '*COOL*' v.s '*WARM*', '*SOFT*' v.s '*HARD*', '*SLIGHT*' v.s '*HEAVY*' are constructed. From the statement described above, coloring planning associating with psychologically linguistic meaning becomes the novel field of color image processing. The motivation of this paper is to study a coloring mechanism for interior image. This method is designed to achieve a satisfying affective human response (i.e. pleasure/unpleasure). However, the '*satisfying affective*' is too abstract for computer applications. Fortunately, a quantitative evaluation of color harmony has been developed[1, 2]. It is possible to communicate the measurement of color harmony with computer applications. So the coloring mechanism can be designed on the basis of color harmony principle.

Besides, T. Terano *et al.*[3] were the team who studied the intermediation between image and human through natural language. They developed an automatic coloring system of a landscape. They expressed the coloring rules with natural language and changed them with the fuzzy sets. There are few groups which begins to concern the psychological meaning of color in the image. K. E. Burchett[4] said two or more colors seen together to produce a satisfying affective response are said to be in *harmony*. Color harmony is represented by a range of meaning for several conditions. He integrated twelve attributes to describe color harmony from nine books about color. The twelve attributes are *system, intuition, family, interval, affinity, appropriateness, area, juxtaposition, angular size, relative size, proximity and configuration,* and *dynamics*.

Our objective is to proposed a coloring system for interior image on the basis of color harmony principle. This system emphasizes the characteristic of automatic coloring by modifying color linguistic distribution(CLD) on a 1D color image scale of 'CHEERFUL-SILENT'. Based on the CLD, global color harmony of the image can be analyzed. Also, the color of inharmonious image can be specified as a harmonious one by using the technique of histogram specification. We expect that the resultant output images generated by the proposed system can not only follow public fashion trends, but also satisfy personal preference/disgust. These considerations of design are all on the basis of human psychological response.

2 Quantitative Evaluation of Color Harmony

There is a mind-oriented feature space, called *image scale of "WARM-COOL" and "SOFT-HARD"*, which is usually used by color designers to analyze color on the basis of linguistic meanings. Generally, the image scale must be resulted from questionnaire analysis or assigned by experienced color designers to represent public trends. A computer-determined one-dimension image scale of "*CHEERFUL-SILENT*" is defined[1, 2] on the basis of fashion color collection [5] for interior images. Therefore, a new linguistic feature of color linguistic distribution(CLD) is described. The CLD is described by a *distance-based color linguistic quantization*(DCLQ) algorithm, and is illustrated by Figure 1. By the algorithm, the CLD is defined as the histogram of color linguistic value in the 1D image scale of "CHEERFUL-SILENT". Based on corresponding CLDs, color harmony of interior images could be quantitatively judged by its similarity.

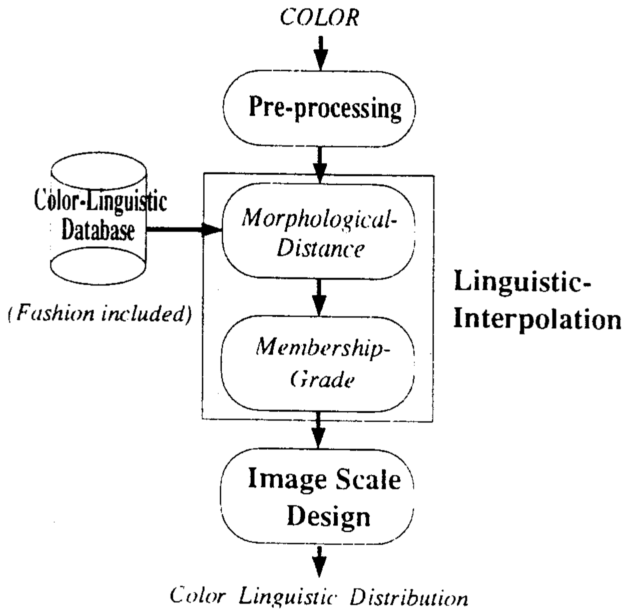

Figure 1 Flow chart of DCLQ algorithm to determine CLD[1,2].

A number of assumptions and definitions must be explained first before we introduce this image scale :

1. That different colors correspond to a similar linguistic meaning is the *many-to-one* mapping based on the algebraic theory for human's color vision. That is, if colors viewed approach each other, the corresponding linguistic meaning would be also similar. However, the criterion is not necessary to be true for the reverse situation[1].

$$\begin{aligned} &\textit{if} \\ &color_1 \approx color_2 \\ &\textit{then} \\ &color\ linguistic\ meaning_1 \\ &\approx color\ linguistic\ meaning_2 \end{aligned} \tag{2.2.1}$$

2. Fashion colors can maintain for a long time (e.g. a season) for the same regional people.
3. *Color linguistic grade* means a value defined on the image scale.
4. Color linguistic distribution (CLD) means the histogram of the color linguistic grade of processed image on the image scale.
5. The meanings of the designed image scale are that CHEERFUL is located on the negative scale, and the SILENT on the positive scale.

3 Proposed System

Due to the limitations of the developed color image scale model, a basic assumption have to be made for the input image: ***Regions needed to be colored is uniform and flat.*** In order to introduce the system structurally, we divide the system into three major functional blocks : *color linguistic coding, modification of inharmoniously linguistic grade*, and *color linguistic decoding*. The flow chart is shown as Figure 2.

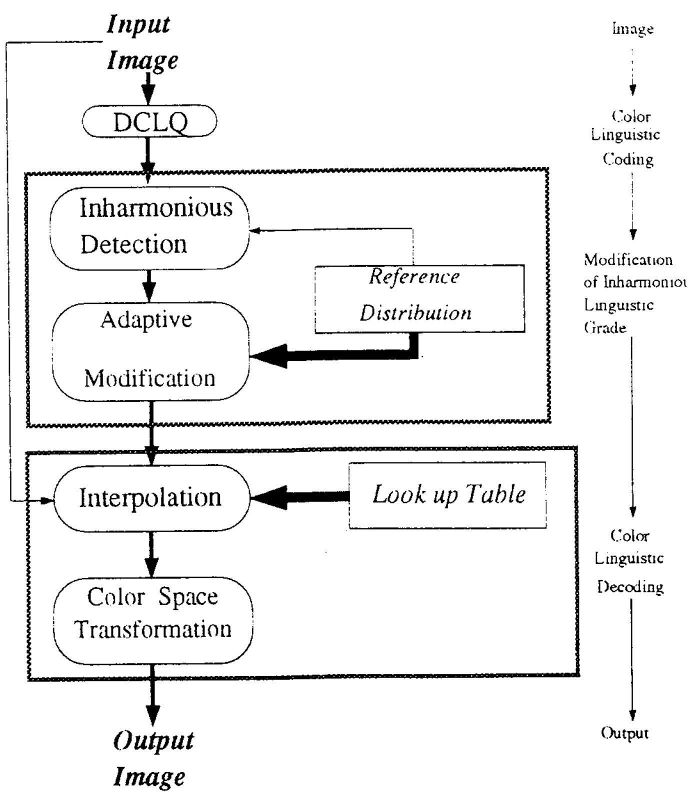

Figure 2 Flowchart of proposed system.

Color Linguistic Coding

The information employed is only the original image and color linguistic distribution(CLD) in the proposed system. The inharmonious color in the image appears the linguistic meaning of 'CHEERFUL'. We will further process the data of CLD and detect the inharmonious color of image in the color image scale domain. We apply the concept of *histogram specification* to adaptively modify color linguistic grade of original inharmonious color.

The data size of CLD is the same as the image size. If the CLD is analogous with a grey-level image, the bright-and-dark change of grey-level image can be observed by the histogram distribution. Similarly, we can also expand the CLD on the one-dimension color image scale, and achieve an actual illustration.

The inharmonious perception is generally due to a larger region of CHEERFUL's colors, and generates a higher *dominant inharmonious peaks* at CHEERFUL side by the transformation of color image scale model. We can detect the position of dominant peaks in the color image scale via suitable decision of the threshold concerning probability.

Modification of Inharmoniously Linguistic Grade

After detection of the inharmonious grade, we will adaptively modify it to the position of SILENT side continuously. The ideal-defined distributions and a standard harmony distribution of the color interior image play a supervisor role, and support us to find a satisfied grade at SILENT side. The concept of histogram specification is described in the following.

- *histogram specification*[6]

If u and v are given as discrete random variables that take values x_i and y_i, i=0,1,...,L-1, with probabilities $P_u(x_i)$ and $P_v(y_i)$, respectively. Define

$$w \triangleq \sum_{x_i=0}^{u} P_u(x_i)\ , \quad \tilde{w}_k \triangleq \sum_{i=0}^{k} P_v(y_i)\ , k = 0, \ldots, L-1 \tag{3.2.1}$$

Let w^* denotes the value $\tilde{w}_n$ such that $\tilde{w}_n - w \geq 0$ for the smallest value of n. Then $v^* = y_n$ is the output corresponding to u.

Color Linguistic Decoding

We get a set of new CLD data after completing modification of the linguistic grades. The next step is how to invert the CLD to the output interior image. We want to invert the color linguistic grades back to the color tristimuli of R,G,B values, and is analogous with the meaning of image decoding. Recall the principle of color linguistic quantization representation, which the colors map to the linguistic grades is a many-to-one mapping. That is, the different colors located on the various positions of image may map to the same linguistic grade. It is difficult to map directly the color linguistic grades back to the colors and their corresponding positions in the output image. Therefore, we employ the auxiliaries of original input image and a *look up table* generated by the DCLQ algorithm to construct the output image successfully. We give a graphic representation to explain the principle of color interpolation as Figure 3.

$$(Luv)_X = w_A \cdot (Luv)_A + w_B \cdot (Luv)_B + w_C \cdot (Luv)_C \qquad (3.3.2)$$

As those shown in Figure 3 shows, we must decide the weighting coefficients for CIE1976(L*u*v*) color space. The weighting coefficients are designed according to the distance relation among different linguistic grades on the color linguistic axis (i.e the color image scale). The detailed mathematic expressions are stated as follows :

$$\begin{aligned} w_A &= \frac{\alpha\,(D^2_{XB} + D^2_{XC})}{2 \cdot (D^2_{XA} + D^2_{XB} + D^2_{XC})} \\ w_B &= \frac{\beta\,(D^2_{XA} + D^2_{XC})}{2 \cdot (D^2_{XA} + D^2_{XB} + D^2_{XC})} \\ w_C &= \frac{\gamma\,(D^2_{XA} + D^2_{XB})}{2 \cdot (D^2_{XA} + D^2_{XB} + D^2_{XC})} \end{aligned} \qquad (3.3.3)$$

We also explain why the decision of weighting coefficients uses the square of distance among some linguistic grades . After we have tested on the color linguistic axis, the change of colors corresponding to the variation of linguistic grade and the perception difference of human's visual psychology is generally not the relation of linearity, but owes the trend of nonlinear variation. Therefore, we design the square factor to approximate the exponential relation.

4 Experiments

Some experimental results are made by the proposed system. All of the simulation programs are written with C language and run on the workstation. There are three experimental topics in this study. The color-plates image is employed to test the system's coloring function (color linguistic decoding). The CLD of interior image is modified with respect to some ideal defined distributions which represent 'VERY SILENT', 'SILENT', 'SLIGHT SILENT', respectively. A actual condition of standard harmony distribution is applied as a supervisor role to modify the CLD of interior image.

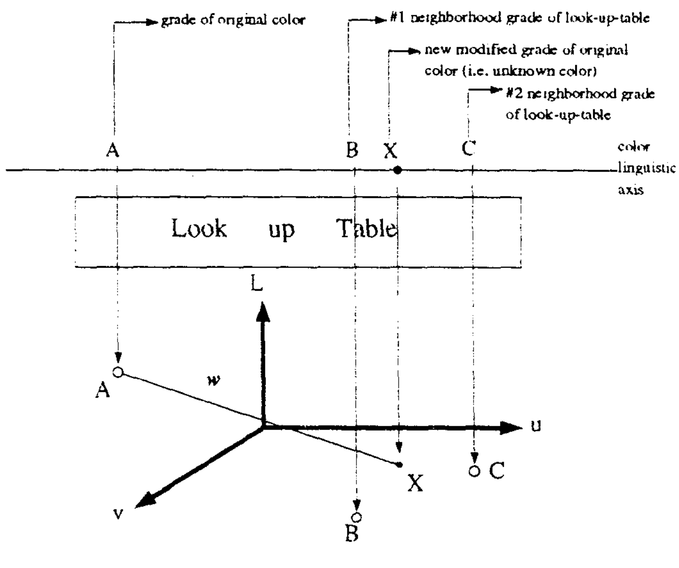

Figure 3 Graphic representation of color interpolation.

Notation

We explain the meaning of some symbols before showing the results.

- VS : 'VERY SILENT' distribution
- S : 'SILENT' distribution
- SS : 'SLIGHT SILENT' distribution
- SHD : standard harmony distribution

4.1 Color-plates

The object of this experiment is to identify the correction of *color linguistic decoding* with a color-plates image by using a *bypass* procedure of the "modification of inharmoniously linguistic grade" demonstrated in Figure 2, also, results are shown in Figure 5.

This is a many-to-one mapping that the proposed system transforms the color interior image into the CLD of color image scale. The CLD contains the spatial information of colors which are in the input image. We complete approximately this task in which the output image is reconstructed from the CLD by the look up table. Therefore, the mechanism of color linguistic decoding is the most important part for the correct output result. We get the correct verification by the result of Figure 5. The two images are a little different actually. The corresponding color difference is still in the tolerable range of human visual perception. So the output image is still correct.

4.2 Interior Images

The pattern is a real bedroom image in this experiment. These interior images are background-rendered due to the assumption of system. We employ four harmony distributions as the reference for modifying the CLD of input image. They contain three ideal-defined harmony distribution and a standard harmony one. The meanings of three ideal-defined distributions are 'VERY SILENT', 'SILENT', 'SLIGHT SILENT', respectively. Their shapes are similar to the fuzzy set and shown in Figure 4. The object of this experiment is that the output images are expected to be harmonious images.

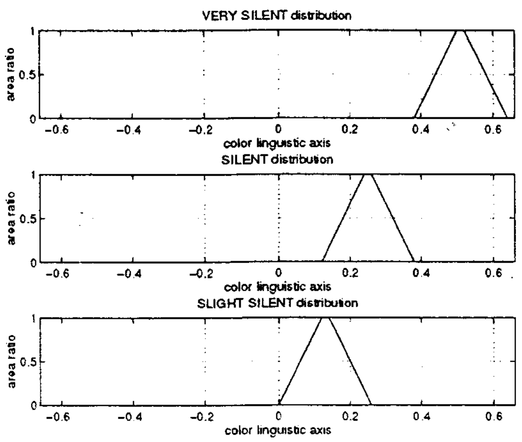

Figure 4 Three ideal-defined harmony distributions.

Figure 6 (A) and Figure 7 (A) show two typical input images, in which the input interior images can be divided into two sets of different grade of color harmony. One is gorgeous colors (e.g. Red, Yellow, Blue), the other is turbid colors (e.g. Turbid1, Turbid2, Turbid3). The system modifies the dominant inharmonious peak to adaptive position with respect to four different reference distribution by the technique of histogram specification. The modification of CLD is reconstructed by the mechanism of color linguistic decoding, shown in Figure 6 (B)-(E) and Figure 7 (B)-(E). Since our proposed system can not exactly satisfy with each person's preference, therefore two additional candidate colors are given to increase selective flexibility of the system.

5 Conclusion and Discussion

A coloring system for interior image is proposed in this paper. The system is constructed on the basis of a previously developed 1D color image scale of 'CHEERFUL-SILENT' to quantitatively evaluate color harmony. In the conventional researches of computer graphics, the rendered colors is *manual-based* selection. Our proposed system can *automaticly* coloring the interior image by the technique of histogram specification, considering *the grade of global color harmony*, simultaneously.

Although our system improves the grade of global harmony of input image, the substituted color of resultant image is not an optimal solution. That is, individual person's preference has not been considered, therefore, multisolution outputs are provided. An variation of $\pm\delta$ is added into the specified dominant peak grade after histogram specification has been done.

Besides, the generated path of look up table is not unique, which depends on the application field of coloring. Also, the selection of reference distribution is another influence for output result. Different types of reference distribution have to be decided for different applications. All of the above factors must be considered for applying the proposed coloring system practically. The look up table should be generated by the way of uniformity for color difference, and the shape of reference distributions must be further developed for various applications.

6 References

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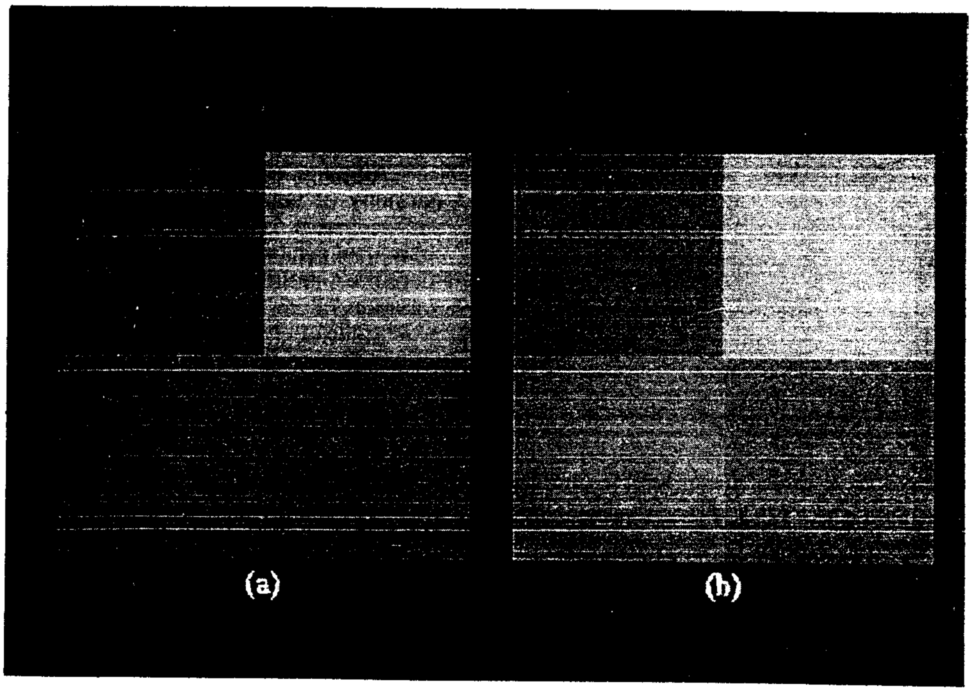
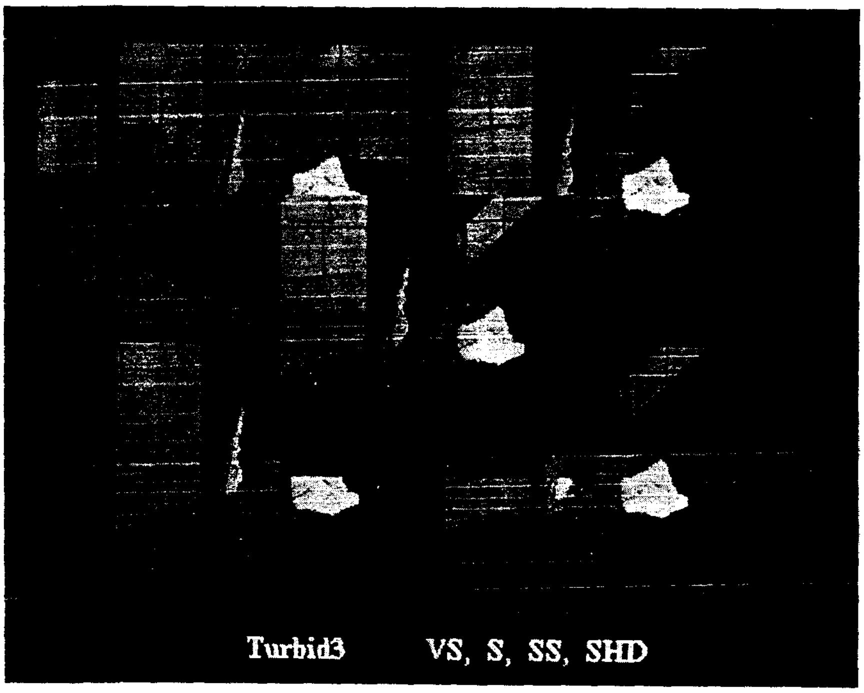


Figure 5 Coloring of color-plates images : (a) original image, and (b) corresponding result.



(B), VS		(C), S
	(A), Turbid3	
(D), SS		(E), SHD

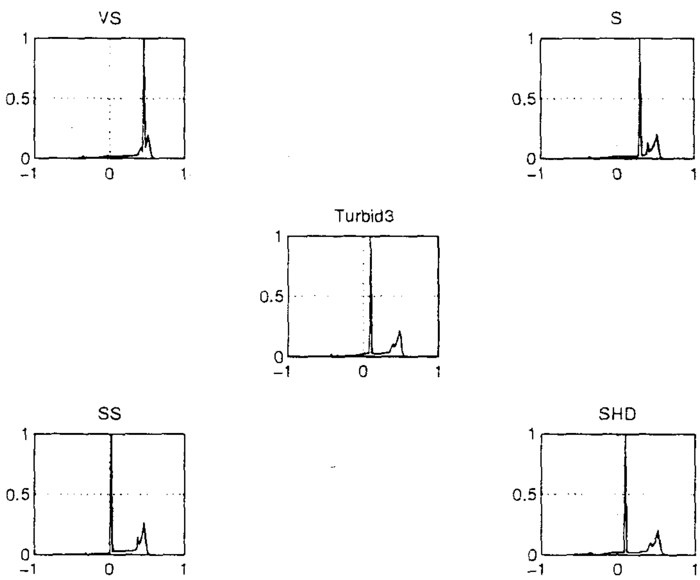
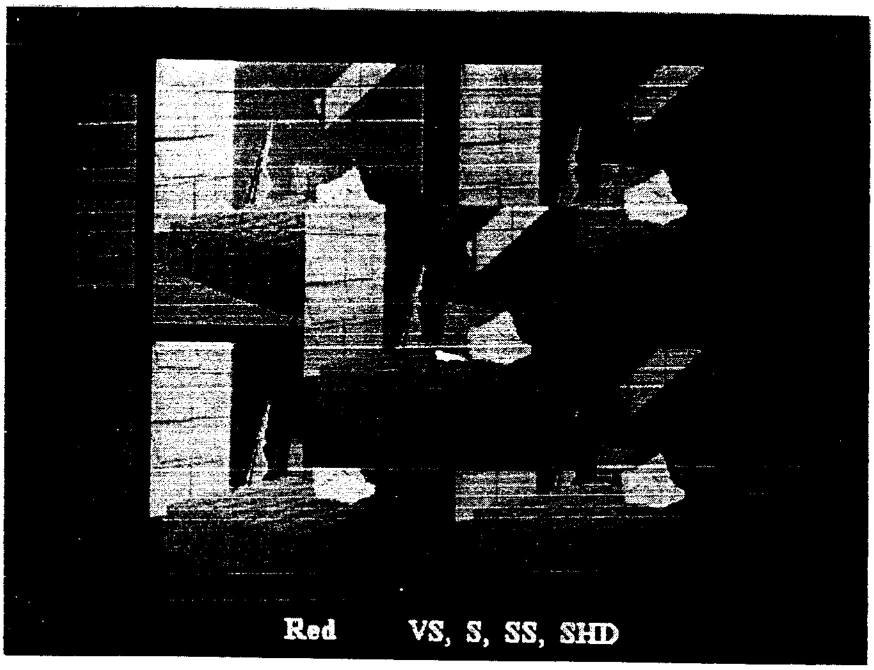


Figure 7 Coloring of interior image '*Turbid3*': (A) original image, and (B)-(E) corresponding results.



(B), VS		(C), S
	(A), Red	
(D), SS		(E), SHD

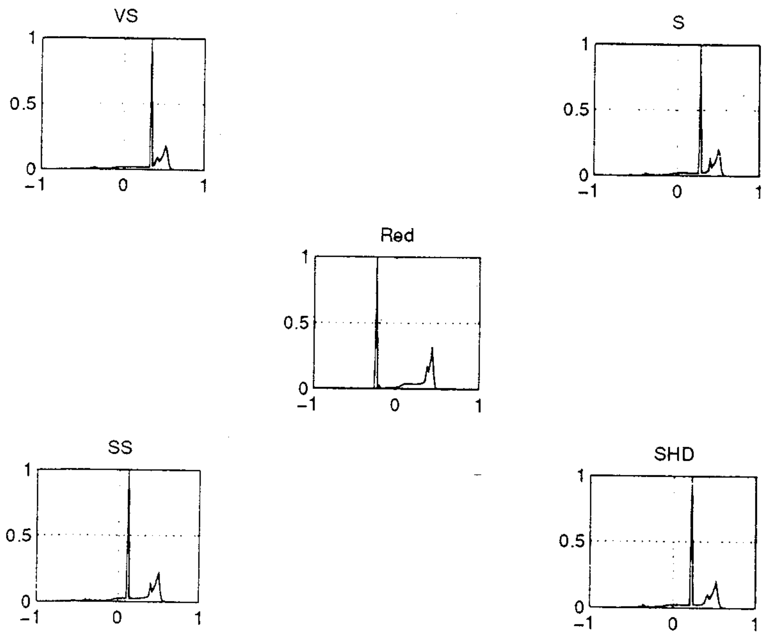


Figure 6 Coloring of interior image '***Red***': (A) original image, and (B)-(E) corresponding results.