ACTA STEREOL 1994; 13/1: 191-196
PROC 6ECS PRAGUE, 1993
ORIGINAL SCIENTIFIC PAPER

COLOR IMAGE UNDERSTANDING THROUGH A PERCEPTUAL APPROACH

Alain TREMEAU[1], Maurice CALONNIER[2], Bernard LAGET[1]

[1] U.R.A 842 -Laboratoire Traitement du signal et Instrumentation
23 , rue du Dr. Michelon 42023 SAINT-ETIENNE Cedex2 FRANCE
[2] I T F. Av. Guy de Collongue B.P. 60 69132 ECULLY Cedex FRANCE

ABSTRACT

Until now, color image analysis has received little attention as regards to perceptual approach. However, it seems intuitively natural to pay more attention to the field of color perception, in order to have a better knowledge of the mechanism which effects color image vision.
The aim of this paper is to review the main aspects of color image analysis which are closely linked to color vision. Due to the complexity of human color perception, we only attempt to mention a few of its principles such as those linked to: - the interaction due to both spatial and chromatic vision. - the measure of the color difference between two elements spatially adjacent or distant. - the prediction of some adaptive chromaticity difference perception thresholds as regards to local or global observations. - the discrimination between asjacent regions marked by a small color variation or when they present distinct color textures. ...

Key words: image analysis, color vision, color discrimination, color aggregation, color texture.

COLOR DISCRIMINATION

The basic obstacles, which have been encountered until now, are linked to a lack of understanding of the human vision mechanism and to the difficulty in studying the human mechanisms which are involved (Stockham, 1972). Thus, if the identification of various regions of an image, as well as their edges, is implicit for the human sight system. This is not the same for digital vision analysis. The difficulty is linked to criteria of homogeneity associated with areas to be highlighted.
Consequently, color image analysis requires access to a wide range of information related to the human vision system of scenes perception (Gershon,1985). Such an approach demonstrates fully that it is possible to "lead in the direction of building systems which will be able to understand images as the Human does" (Bumbaca, 1987). The improvements achieved will necessarily ensure progress in color image analysis, in a visual sense.
All data related to scenes perception are registred early, in parallel, over the visual field and get to the brain via different types of path, even though they initially come from the same sensors. It is only in a later stage that each of these data are identified separately, requiring focused attention and specific treatments. These treatments join up or overlap depending on contextual information, nevertheless most of the time they can be dissociated (Callaghan,1989).
Among the criteria that enable one to judge the homogeneity of an area, color information is the main parameter that comes directly into account in visual evaluation (Gershon, 1985). This feature interacts with all the other data, and more particularly with contours, due to the fact that color seems to fill areas surrounded by contours.

- Color enables the human sight system to analyse colorimetric difference, between two elements, in terms of lightness (black-white axis), hue and saturation (green-red axis and blue-yellow axis). Consequently, the color representation system, to be used, needs to include these three aspects in its representation.
- Likewise, the color representation system, also needs to be uniform over the entire color space, in order to avoid any distortion between the physical measure separating two colors and the subjective measure resulting from it for the human sight system.
- From a perceptual point of view, it is not conceivable to consider the color space as the superpositioning of three colorimetric axes from which color measures could be obtained more easily. Indeed, two colors relatively close each other in the color space may not be so close with regard to each of the axes. It is necessary then to consider the color space as an entire three-dimensional entity.

Let h be the image function. Then, the global average colorimetry representative of the studied area A can be defined by :

$$\bar{h}_G = \frac{1}{card\ A} \sum_{(x,y)\in A} h(x,y) \qquad (1)$$

and the global colorimetric dispersion, of the studied area, around its representative average colorimetry can be characterized by :

$$d_G{}^2{}_{moy} = \frac{1}{card\ A} \sum_{(x,y)\in A} \left\| h(x,y) - \bar{h}_G \right\|^2 \qquad (2)$$

The more extended the global colorimetric dispersion, the less the area being studied can be considered as an homogeneous color shape, but rather as a multitude of colorimetric points perceptually differentiable, that are spatially grouped together. Consequently, to be perceptible as a single visual entity, an area needs to have its global colorimetric dispersion limited to a certain degree of homogeneity. This latter is relative to the notion of just noticeable difference, which corresponds to the maximum degree of focalization below which one cannot perceptuelly differentiate the colorimetric elements of one cluster (MacAdam, 1942).

Let us emphasize now some phenomena related to this global colorimetric dispersion:
- The presence or the absence of well defined principal axes indicates that color distribution is more or less dispersed around one or several colors. It suggests that certain colors are more or less discriminating in the studied cluster perception.
- The extension of the first principal axis represents the color dispersion for which the color variation is the greatest. The longer this axis, the less homogeneous the cluster. Such a criterion indicates a **color drift** between two color components. The shorter this axis, the more homogeneous the cluster. Such a case indicates an unique color component. (The orientation of this principal axis indicates the dominant colors scale linked to this dispersion).
- The radial distribution function characterizes color dispersion around color average. It indicates if the distribution is more or less extended.
- The local density function characterizes locally the color dispersion in terms of clusters or isolated points. The more numerous the clusters, the less homogeneous the studied area. Such a criterion indicates that this area needs to be partitionned into several color components. On the other hand, the more numerous the isolated points, the more textured this area. Such a criterion indicates a **color texture**. - ...

COLOR AGGREGATION

The next process, which comes after discrimination, concerns the aggregation of elements in regions. This mechanism organizes the scene into meaningful units, that are homogeneous with respect to one or more features. Among them, the contour parameter, or more precisely the mechanism of spatial contrast is, without any doubt, the most useful one involved in the perception of an area. Color contrast perception is a major subjective topic belonging to the domain of psychology, so most of the time its objective physical identification is not easily applicable. The detection of contrasts is generally independent from chromatic vision, only lightness data makes it useable. It may, however, prove unsufficient, particularly when the contour data is purely chromatic (Gershon, 1985). Consequently, all elements of the image plane concerned by this mechanism need to be colorimetrically analyzed in comparaison to their neighborhood elements. Several aspects of color contrast identification have been studied, among them, let us emphasize some phenomena as:

- Afterimage (successive contrast): which occurs when we continue to see an object, for a few moments, after moving our eyes to an another object, influencing consequently the color appareance of the latter.
- Simultaneous contrast (spatial contrast): which occurs when the background influences the perceived color of a region. That phenomenon includes an afterimage contribution, because our eyes fix this region, move on to its background and move on again to this region.
- Edge contrast (border contrast): which occurs when two juxtaposed areas of uniform colors are viewed (to the boundary between the two areas), one with a relative enhancement of its color and the adjoining one with a corresponding attenuation of its color. Thus, regions of hight relative contrast are amplified and regions of low relative contrast are attenuated (Grossberg, 1991).
- Subjective contours: which occur when edges are perceived, but are no justified by noticeable physical changes. - ...

Visual texture segregation is a process that is accomplished relatively early in perception, this with a widely dispersed focus of attention. On the basis of the Gestalt notion of similarity grouping, it has been proposed that the process of texture segregation will be enhanced not only by high dissimilarity of elements between regions, but also by high similarity of elements within regions (Callaghan, 1989). Thus, this segregation is determined by the context in which a target region is embedded.

Moreover, the wider the range of color, the more the human vision system privilegies at first a "sampling" of each area to the detriment of the sharpness of each of them separately. It is only in a second time that this system improves its judgement on each area through a focusing process. In fact, there is no dichotomy between first a preattentive and further an attentive stage, but an attention varying along a continuum during perceptual process (Callaghan, 1989). Hence, the justification of a process of descending hierarchical clustering that progressively sharpens each of the studied areas, until all areas obtained are sufficiently homogeneous to constitute visual entities as they are perceived by the human vision system.

In fact, the notion of shape depends on the degree of focusing being sought. Thus, it may work out, within a given shape, colorimetric dispersion is sufficiently great to let several sub-shapes to be seen, in so far as we focus our attention a bit more on the shape being studied. It is therefore necessary to adjust the thresholds linked to the dispersion to the degree of focusing sought.

We can observe a phenomenon of embedding shapes, each shape containing sub-shapes, which themselves contain sub-shapes etc. These notions involve two visual characteristics that are quite complementary to each other. The first takes place in the context of global vision, the characterization of a shape is done through differentiation with other shapes which are in its neighborhood. The second involves the characterization of the shape itself, according to the elements composing it, it therefore takes place within the context of a local vision (Grossberg, 1991).

Therefore, a region is a spatial entity whose spatiocolorimetric distribution displays a certain criterion of visual homogeneity which includes several considerations both of colorimetric and spatial nature.

SPATIOCOLOR ANALYSIS

Let
$$V(x,y) = \left\{ (x',y') \in P \ / \ (x',y') \neq (x,y) \ \ and \ \begin{matrix} x - x_0 \le x' \le x + x_0 \\ y - y_0 \le y' \le y + y_0 \end{matrix} \right\} \quad (3)$$

be a neighborhood, in image plane P, for the pixel (x,y). (This neighborhood needs to be not too great in order to characterize the local spatiocolorimetric surrounding of this point). This idea of neighborhood integrates the focusing process, previously dealt with, by taking into account the various sensitivities of the human sight system. This focusing is more or less accentuated depending on the nature of the neighborhoods under consideration. Thus, the more perturbed and nonhomogeneous the neighborhood, the less the focusing activity required.
The local average colorimetry representative of the studied area can be defined by:

$$\bar{h}_L(x,y) = \frac{1}{card\ V(x,y)} \sum_{(x',y') \in V(x,y)} h(x',y') \quad (4)$$

and, the local colorimetric dispersion, of the studied area, around its average colorimetry representative can be characterized by:

$$d_L{}^2{}_{moy}\ (h(x,y)) = \frac{1}{card\ V(x,y)} \sum_{(x',y') \in V(x,y)} \left\| h(x',y') - \bar{h}_L(x,y) \right\|^2 \quad (5)$$

The interest of such a criterion is that it defines a measure of local contrast of one point with relation to its neighborhood.

Let
$$d_L{}^2{}_{\max}\ (h(x,y)) = \max_{(x',y') \in V(x,y)} \left\| h(x,y) - h(x',y') \right\|^2 \quad (6)$$

with such a measure, we don't take into account an average error, but rather the observable maximum error. Consequently, this measure focuses on that element of the neighborhood in which the perceived difference is the most noticeable. Therefore it corresponds to the human vision system's sensitivity in the best way.

- To each pixel (point element) $(x,y) \in R^2$, corresponds a color $(L,a,b) \in R^3$(L,a,b) . Therefore, we can define a coxel (color element) as being a element $((x,y), (L,a,b)) \in R^2 * R^3$ (Fig. 1).
- To each spatial shape corresponds a cluster in the color space and a cluster in the spatiocolor space. Moreover, a shape is perceived as such if its elements are enough homogeneous both for global color distribution and for local color distribution.
Thus:
- We can notice that a color drift which is regularly distributed on the spatial plane corresponds to a **spatiocolor drift.** - On the other hand, a color drift which is randomly distributed on the spatial space correponds to a spatiocolor texture.
- In the same way, a color texture which is randomly distributed on the spatial space corresponds to a **spatiocolor texture**. - On the other hand, a color cluster constituted around several color components which are regularly distributed on the spatial space correponds to a group of spatiocolor components.

Perceptually the human sight system gives more importance to local irregularities than to a global drift. Thus, a smoothly varying region may globally be unnoticeable within an area, whereas local disturbances, of the same amplitude as the drift observed for the varying region, may locally attract attention. So, it is difficult to establish a splitting threshold between the notion of disconnected shapes and that of textured shapes. Nevertheless we can used the following measure:

$$d^2\ (h(x,y)) = \frac{1}{card\ V(x,y)} \sum_{(x',y') \in V(x,y)} \left\| h(x,y) - h(x',y') \right\|^2 \quad (7)$$

which defines a measure of the emergence of one point with relation to its neighborhood (for the specified area). The interest of such a criterion is that it reflects variations in contrast which may

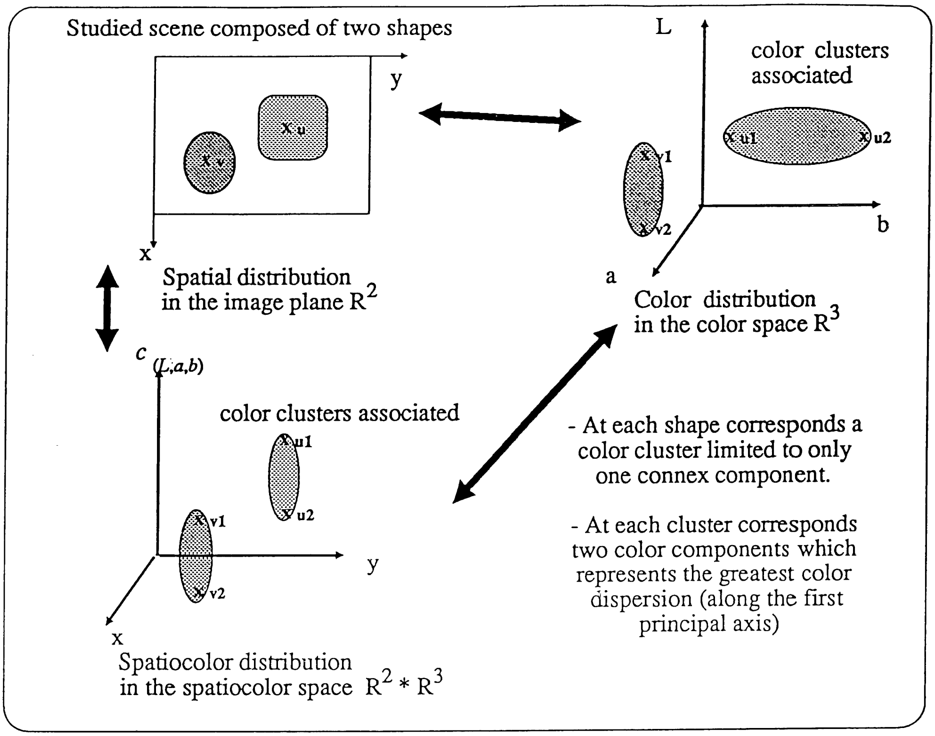

Fig.1. Exemple of color and spatiocolor representations associated with the studied image.

occur in the neighborhood of a given point. The lower this contrast, the more homogeneous the image. Thus, the degree of nonhomogeneity linked to a zone is directly connected with the relative contrast of the center of the zone with reference to its surrounding. In the same way, we can establish a parallel between the degree of nonhomogeneity associated with a neighborhood, and the degree of sensitivity associated to it (Balasubramanian, 1991).
Therefore, we have to establish an adaptative color difference perception threshold which takes into account the degree of sensitivity associated with each neighborhood.
Thus, the difference perceived between two color does not only result from an absolute measure of punctual differences, but also from the relative difference of their contrasts.
These aspects have been implemented and tested with success in color image analysis, in particular in quantization, segmentation or pattern recognition.

REFERENCES

Balasubramanian R., Allebach J. A new approach to Palette selection for Color Images. Journal of Imaging Technology; Vol.17, No. 6, Dec. 1991: 284-297.
Bumbaca F., Smith K.C. Design and implementation of a colour Vision model for Computer Vision applications, Computer Vision Graphics and Image Processing, Vol.39, 1987: 226-245.

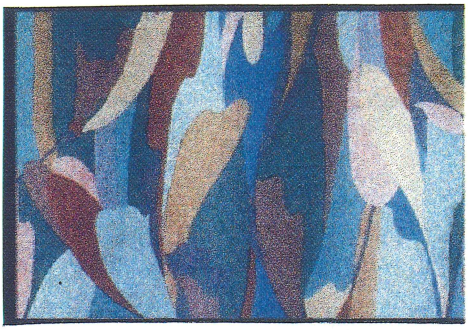

Fig. 2. Image studied

Fig. 3.* Masking of various image areas, depending on their degree of homogeneity.

* *With - homogeneous neighborhoods are displayed in green.*
- pseudo-homogeneous neighborhoods are displayed in bright blue.
- unhomogeneous neighborhoods are displayed in dark blue.

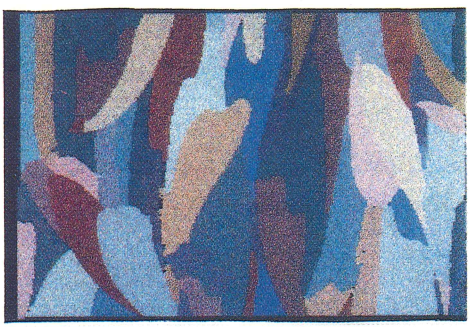

Fig. 4. Masking of shapes detected. Each mask is represented by the average colorimetry linked to its corresponding shape.

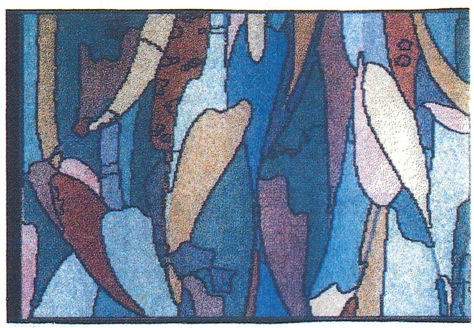

Fig. 5. superpositionning of contours detected on the original image

Callaghan T.C. Interference and dominance in texture segregation: Hue, geometric form, and line orientation. Perception & Psychophysics, Vol. 46, No. 4, 1989: 299-311.
Gershon R. Aspects of Perception and Computation in Color Vision. Computer Vision Graphics and Image processing; Vol. 32, 1985: 244-277.
Grossberg S., Wyse L. A neural network architecture for figure-ground separation of connected scenic figures, Neural Networks; Vol. 4, 1991: 723-742.
Mac Adam D.L. Visual sensitivities to color differences in daylight. J. Opt. Sc. Am., Vol. 32, No. 5, 1942: 247-274.
Stockham T.G. Image processing in the context of a visual model. Proc. of the IEEE, Vol. 60, No. 7, July 1972: 828-842.