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A Computational Model for Texture Perception with Chromatic and Achromatic Images

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***Abstract*- We have developed a new computational model for texture perception which is physiologically plausible and mimics human performance. Our model tries to simulate the visual processing characteristics by incorporating mechanisms tuned to detect luminance, orientation, spatial-frequency and color, which are characteristic features of any textural image.We obtained a very good correlation between human performance and our model simulations with various strategic texture patterns. The highlights of our model are incorporation of chromatic mechanisms to treat color images, in addition to grey-level ones, and the extension of the concept of double-opponency beyond color. The model could be utilized in the area of image processing, machine vision and pattern recognition, and scientific visualization.**

I. INTRODUCTION

Texture segregation has been thought to be the result of early visual processes. These early visual processes have been studied in both physiological and neurophysiological experiments. As a result of these experiments several computational models have been developed for texture segregation [1]. Most of the models have been in the luminance domain and deal with grey-level images. The human color vision system can discriminate about two million color graduations with which to detect the contours of objects in the external world (500 for brightness x 200 for hue x 20 for saturation). Thus most of the models proposed restrict themselves to a sub-space of 500 levels. This prompted us to develop a texture perception model which goes beyond grey-level images into the realm of the color world. In our visual cortex, there are a special class of cells called double-opponency cells which fire optimally to a color contrast or a color edge. We have successfully modelled such cells and extended this concept of double-opponency to other attributes such as orientation.

II. MODEL DESCRIPTION

We employed opponent mechanisms in a texture model, the block diagram of which is shown in Fig.1. In designing our model we make certain assumptions which are to a certain extent neurophysiologically justified. (1) The image signal is composed of a luminance component L(x,y) and a chromatic component C(x,y), each being processed by separate pathways with some secondary interactions. (2) There are four types of domains, labelled according to the population of cells that they contain: Luminance-nonOriented(LnO- Above & Below), Luminance-Oriented (LO- AH, AV, BH, BV), Color-nonOriented(CnO-Green & Red), and color-Oriented(CO-GV, GH, RH, RV). The first two types of domains are essentially color-blind and operate entirely in the achromatic domain. The last two types of domains are essentially luminance-blind and care only about wavelengths. The CO domain is simultaneously tuned to both color and orientation.

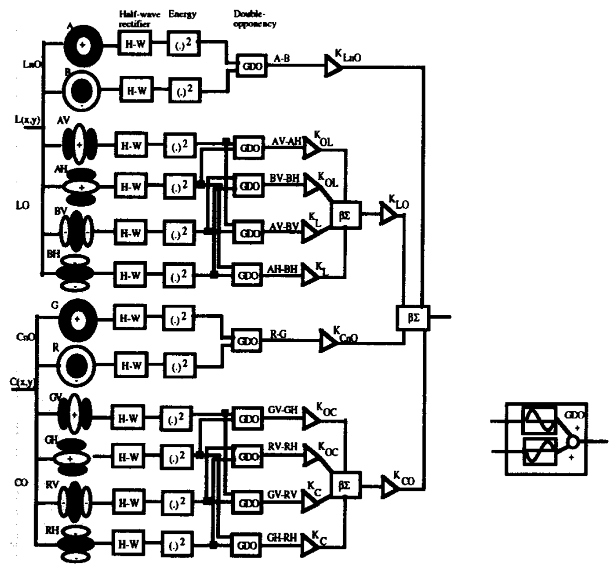

Figure 1: Block diagram of the texture segregation model

The model as shown in Fig. 1 has been implemented in four stages: 1) A set of linear filters (simulates the V1 simple cells in the visual cortex) tuned to specific spatial frequencies that are isotropic or oriented, with separate domains for luminance and color; The luminance filters sensitive to brightness resemble the broad-band ganglion cells and the chromatic filters resemble the single-opponent chromatic cells. (2) The outputs of the linear filters are half-wave rectified and then squared. These operations are performed to eliminate spurious responses and thereby increase the signal to noise ratio. Such non-linear operations have been observed in the cat's visual cortex [2]. Once the signal is processed by the half-square operator, the next task is to extract the texture edge. In our model we have extended the concept of double-opponency (found in the visual cortex in human color perception) to orientation and luminance to extract texture edges (shown as GDO in Fig. 1) Double-opponency is implemented by the box GDO in Fig.1. The two inputs to the box are convolved by G' and -G' respectively and added (G' is the first derivative of a Gaussian). The shape of G' and the phase difference of 180° ensure that the two inputs have an excitatory and inhibitory effect, respectively, in one lobe of G' and their roles are reverse in the other lobe, which is the main property of any double-opponent unit. (4) After the strength of the texture edge is computed in each opponency pair, the signals are combined first within each of the four domains and then across domains through ß summation [3], which allows the signals to be weighed and summed probabilistically, to account for the degree of independence of the operators.

III. RESULTS

We tested the predictions of our texture models against texture discrimination performances measured with a large variety of texture pairs built from texture elements, defined by their orientation,luminance and/or chromatic contrast [4]. The stimuli contained eighteen texture pairs made by a combination of luminance, color and orientation attributes is shown in Figure 2.

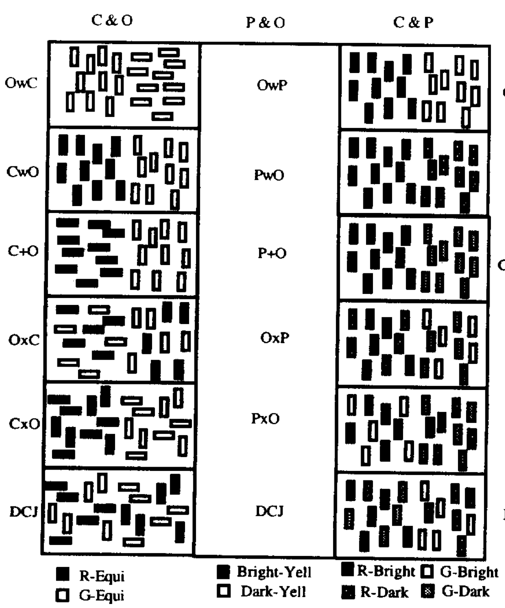

Fig. 2 The eighteen texture pairs used in experiments and model simulations.

The average ease of discriminability is plotted against the 18 texture pairs (Fig. 2) in Fig. 3 for a human observer (filled squares). The same stimuli were input to our model and the results are also shown (solid lines). Note that the trend order of discriminability predicted by our model matches the order found psychophysically (correlation coeff. is .92, for this restricted domain of stimuli).

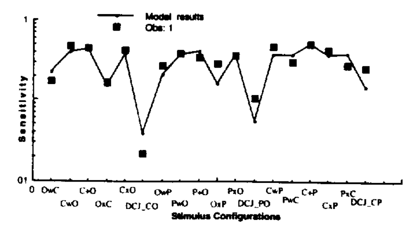

Figure 3: Sensitivities (filled squares) and simulations (solid curves) for the 18 texture pairs shown in Fig. 2

We also tested our model on a stimulus which has radial lines at the center portion of the image and concentric lines at its periphery. This figure shown in Fig.4 clearly has a circular texture edge. The response from our model is shown to its right which indicates the high activity circular edge.

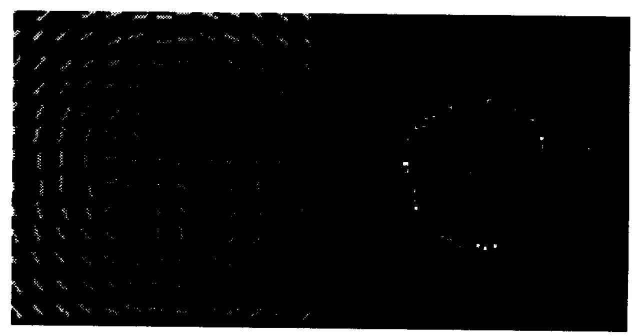

Figure 4: Circular test image and the model output.

IV. CONCLUSIONS

The model proposed above is based on the generalization of the concept of double-opponency to attributes other than color, such as luminance and orientation. It is the first attempt to incorporate color in texture segregation algorithms. It remains to be seen whether such double-opponent operators can be isolated in neurophysiological experiments.

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