TEXTURE ANALYSIS USING A MODEL OF THE VISUAL SYSTEM +

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ABSTRACT

As texture is very important for segmentation of natural scenes we work on a criterion to decide, whether two local areas show identical or different textures. Since perceptibility of differences in texture is only defined by human texture perception, recent physiological measurements and results of psychophysical research are considered and a model of human texture preception is introduced. The model is essentially based on directional filters, as it is well known that cortical cells respond to contours of a limited or wider range of orientations. Experiments using features derived from the developed model have been performed and the results showed an average rate of accuracy of 87 % for segmentation of texture pictures, each of them being composed by eight different natural textures from Brodatz' texture album.

INTRODUCTION

Standard methods for the parametric description of textures consist of structural approaches, i.e. the description of micropatterns and their placement rules, or statistical approaches, where first and higher order statistics are estimated from a local neighbourhood utilizing histograms, co-occurrence matrices, run length matrices etc. These methods can be seen as application of standard mathematical tools for solving a particular problem, mostly for discrimination of a finite number of textural classes. Textures and textural differences are not completely definable by mathematical processes. Textures are regular or irregular structures in images that humans perceive as uniform regions. Therefore any algorithm that intends to measure differences in texture for the purpose of an automated segmentation of natural images cannot use arbitrarily defined mathematical tools, but must consider the properties of human texture perception. It is the intention of this research project to find a model of human texture perception for parametric description of textures and for the automatic detection of texture differences in natural images.

MODEL OF TEXTURE PERCEPTION

The proposed model is based on well established properties of the visual system as published for instance by Cornsweet /1/. It includes results of psychophysical research on human texture perception like those published by Julesz/2/ and new physiological measurements from Creutzfeldt and Nothdurft /3/. Figure 1 shows a blockdiagram of the human visual system described earlier by Foith /4/. Due to nonlinear processes in the retina and lateral inhibition of neighbouring cells the visual system shows adaptive properties to varying intensities and performs a bandpass filtering of the incoming image. Physiological measurements have shown that on the way from the retina to the CGL (Corpus Geniculatum Laterale) the image is reduced to its contours step by step. This binary image is further processed in the visual cortex by several two-dimensional filters of different spatial extent and orientation sensitivity in different directions. Since visual image processing includes grey level and contour perception it can be concluded that the superior cortical centers use simultaneously visual imformation from different parts of the visual path. This corresponds to the two parallel paths in the proposed model of Fig. 2. The upper path represents the processing of grey level information and the lower path the processing of the image contours. For simplification of the mathematical description and in agreement with physiological measurements, grey level information can be represented by its first order statistics. In the upper path of the model in Fig. 2 the description of the first order statistics is approximated by the mean value and the variance corresponding to the subjective properties of brightness and contrast. The processing of grey level information is performed mainly by the retina. Therefore the upper path contains a logarithmic characteristic and a bandpass filter (MTF = Modulation Transfer Function) to model the properties of the retina as mentioned above. The lower path on Fig. 2 models the processing of the two-dimensional structural information of texture. For simplification of the modelling the processing steps of the visual system like adaptation, bandpass filtering and contour extraction have been combined in the computationally simple algorithm of "median-clipping". The algorithm of median-clipping works as follows: the grey level of each pixel is compared to the median value of the grey levels in a square local neighbourhood surrounding the pixel. If the present pixel shows a higher grey level than the median value of the corresponding neighbourhood, the pixel is set to bright level. Otherwise it is set to dark. The effect of this binarization which is supposed to model the visual path from the retina to the CGL is demonstrated in Fig. 5b and 5c for different choices of the size of the local neighbourhood. In correspondance with image processing stages in the cortex, that have

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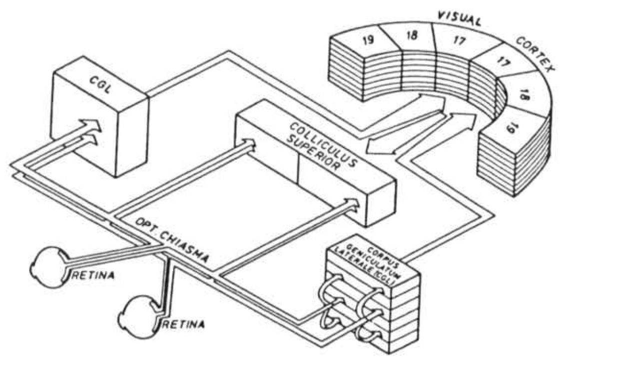

FIGURE 1: Blockdiagram of the Human Visual System

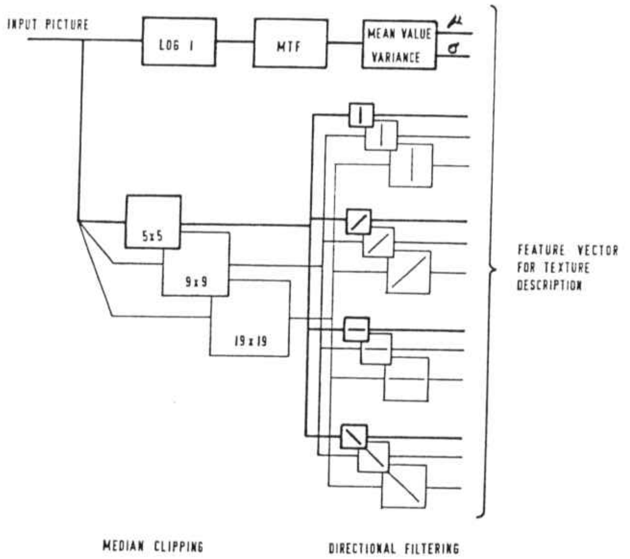

FIGURE 2: Model of the Human Texture Perception

been verified by physiological measurements, the binary contour image is further processed by two-dimensional filters with narrow orientation sensitivity in different directions. In our model (Fig. 2) filters are used with a maximum sensitivity in the four main directions of 0°, 45°, 90°, and 135° to the horizontal line. Subjective properties like coarseness and regularity can probably only be perceived because of the existence of a large number of receptive fields of different spatial extent in the visual system. This can be modeled in Fig. 2 by three parallel filters of different window size for the median filtering and its corresponding set of four directional filters. The parameters for the quantitative description of the structural texture properties are calculated as the mean energy at the output of each directional filter. One of the applied convolution masks for directional filtering is given in Fig. 3. Convolution masks of other orientations and spatial extent are constructed accordingly.

Figure 4 shows as an example for the operation of a directional filter the processing of an artifical test pattern with two textures. Both textures have identical statistical properties of first order, but show different statistical properties of higher order. Test patterns of that kind have been used

0	1	1	1	0
-1	0	1	0	-1
-1	-1	0	-1	-1
-1	0	1	0	-1
0	1	1	1	0

FIGURE 3: Example for a convolution mask with vertical orientation

by Julesz for subjective tests on the spontaneous texture perception of humans. When the test pattern in Fig. 4a serves as an input to the model proposed, Fig. 4b shows the output of one of the directional filters. Figure 4c presents the local mean energy for the output of this directional filter and Fig. 4d gives the segmentation result, when a fixed threshold is applied to the texture energy measure at the filter output.

The present model produces a total of 14 features for texture description. Two parameters in the upper path, μ and σ, describe brightness and contrast and 3 x 4 parameters in the lower path are used for assessment of the structural information like coarseness, regularity and directionality.

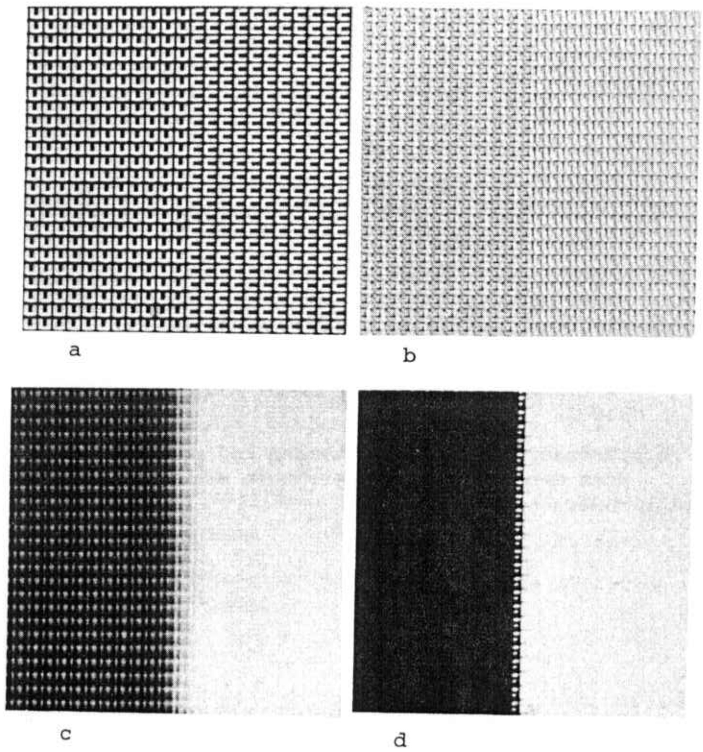

FIGURE 4: Example of the processing of an artifical test pattern by a directional filter

RESULTS

A set of four pictures, each composed of eight different natural textures selected from Brodatz /5/, was used to examine the proposed model. Using a training set of 64 x 64 pixels for each of the eight textures a classifier has been developed and subsequently applied for segmentation of the corresponding composite picture. The segmentation results in an average rate of accuracy of about 87 %.

Figure 5 presents as an example the segmentation of one composite picture of 512 x 512 pixels. Figure 5b and 5c show the outputs of two different sized median-clipping filters for the input image given in Fig. 5a. Figure 5d demonstrates the segmentation result using a set of 14 parameters according to the proposed model. Each of the eight texture classes has been coded by one of eight grey levels.

CONCLUSIONS

Extracting features using a model of the human texture perception promises to become a successfull and universal tool for texture analysis. The proposed model will be improved by further investigation in cooperation with physiologists (O.D. Creutzfeldt and H.C. Nothdurft at the Max Planck Institute in Göttingen/Germany). Moreover we intend to develop an algorithm that is able to segment an arbitrary textured picture without need of a training set, applying features derived from the suggested model. This algorithm will be developed under consideration of strategies that human observers use for image segmentation /6/.

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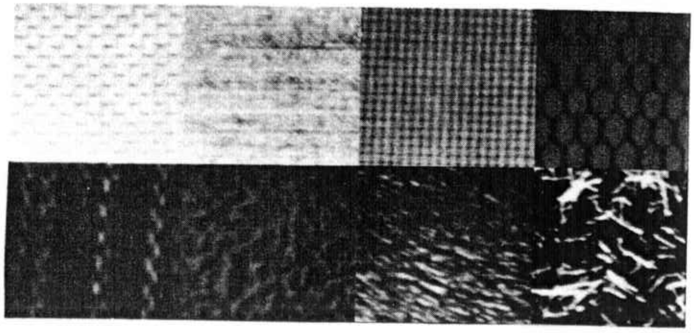

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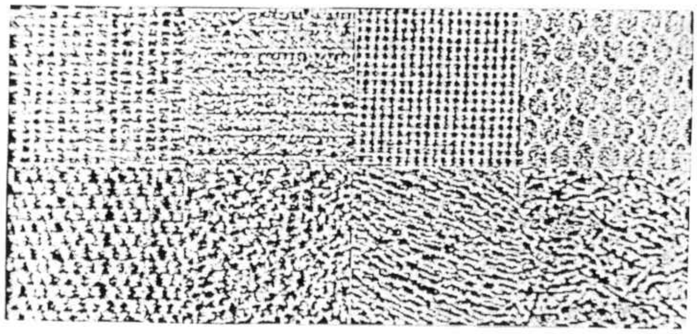

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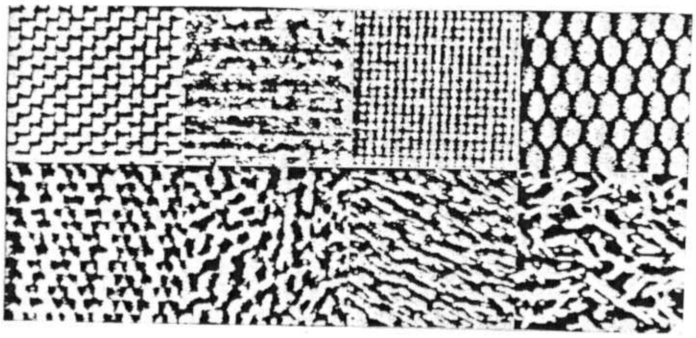
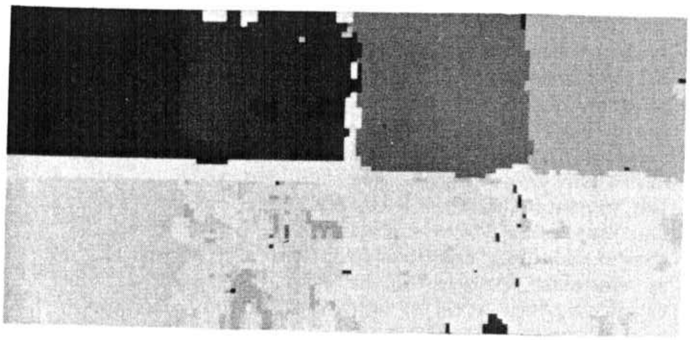


c)



d)

FIGURE 5: Example of the processing and segmentation of an image composed of eight natural textures