Cortical Representation of Texture Primitives

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Abstract

The apparent spatial frequency and orientation organization of the primary visual cortex is used as a basis for texture description. A **F**requency, **O**rientation, neural firing **R**ate, and spatial **P**hase (**FORP**) representation is proposed for the analysis of natural textures and the synthesis of test textures. Higher order texture analysis such as discrimination and segmentation in this FORP space is discussed.

Keywords: texture analysis, vision models, primary visual cortex models

Introduction

Many researchers have tried to duplicate the ability of the human visual system to segment natural scenes based on the different texturing of surfaces. We choose to define texture as that property of surfaces that can be described by the local pattern of spatial variation of intensity. We also take as different textures those that can be differentiated by human perception. In this light, we base our analysis of texture on a model of the early human visual system. In particular, we choose a model of the primary visual cortex since both orientation and spatial frequency information exist here. [1]

We use this information in an orthogonal feature extraction space to generate simple test textures and analyse natural textures.

Texture and the Visual Cortex

Given that the primary visual cortex is well suited to texture computations, is there any evidence that it actually performs them? The following evidence indicates that this could indeed be true.

First of all, Julesz[2] mentions the high speed discrimination ability of human subjects. This implies that texture discrimination is a low level visual function and must be early in the visual chain. Kimchi and Palmer,[3] through the use of perceptual experiments found that texture is processed separately in the visual system from shape and structure. Lastly, Berlucchi and Sprague[4] use lesion studies to deduce that shape and structure encoding does not exist in the primary visual cortex. They suggest the primary visual cortex could be used for texture analysis.

The primary visual cortex appears well suited for texture analysis, it appears to actually perform texture computations, and it can use this information to improve image segmentation.

A Visual Cortex Model

Pollen and Ronner[1] describe a model of the primary visual cortex which outlines various functions of cortical neurons. These functions include the retinotopic spatial map, ocular dominance, orientation, spatial frequency and spatial phase. Hubel and Wiesel[5] first described a small separate processing region in the primary visual cortex as the *hypercolumn*. The *hypercolumn* was responsible for analysing a small area of the visual field for orientation information. The hypercolumn has become the name for the 0.5 mm wide cortical area that contains orientation and frequency selectivity neurons for a small visual region. There exist hypercolumn regions to cover all of the visual field.

Our model of the primary visual cortex is based on this hypercolumn structure. One hypercolumn is modeled as a three dimensional space. The space consists of a spatial frequency axis, an orientation axis, and a spatial phase axis. Each point in this space corresponds to a neuron that is selective to a particular set of frequency, orientation, and phase. A magnitude component is also included in this space to account for the strength of response to this particular set. The magnitude is coded by the neuron as a neural firing rate. This model is a modified two dimensional Fourier space with all symmetric regions removed. The model has been named **FORP** (spatial **F**requency, **O**rientation, neural firing **R**ate, and spatial **P**hase).