Space-variant visual processing: Spatially limited visual channels

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Abstract—A multichannel model incorporating visual inhomogeneity is presented in this paper. The parameters that describe inhomogeneity have been experimentally obtained both at threshold and in several suprathreshold conditions. At threshold, probability summation is taken into account in order to determine the spatial extent of visual channels from experimental data showing an asymptotic increase in sensitivity with increasing grating area. At suprathreshold contrast, the region where luminance variations at several scales are visible has also been found. The results support a spatially limited multichannel model of early visual processing and set out a basis for studying perceptual phenomena from the viewpoint of linear space-variant visual processing.

INTRODUCTION

Visual systems have been designed, through long evolutionary processes, to provide their owners with useful (although only partial) information about the environment. The notion has evolved over the last two decades that early human visual processing has much to do with the extraction of spatial frequency and orientation information. Further, experimental data suggest that this analysis is made on a local basis rather than being globally applied over the whole visual field. Thus, the building blocks of almost all spatial vision models published thus far are a set of entities (loosely referred to as 'channels') which, in turn, are made up of spatially localized subunits (sometimes called 'sensors') which share the same processing characteristics (i.e. point weighting function) and only differ in their particular location in the visual field. According to the conventional definition (see Nachmias, 1977; Graham, 1980), there are sensors of every channel at every location in the visual field. In principle, then, multichannel models consider early processing as being essentially homogeneous. This contrasts with the well-known fact of inhomogeneity: visual performance in any spatial resolution task is best at the fovea and quickly declines with increasing eccentricity, which suggests that visual processing is not the same at all locations in the visual field.

This fact has been incorporated into several multichannel models in one of two different formats. On the one hand, Koenderink and van Doorn (1978) proposed what we will call 'spatially limited channels', whose sensors, differing only in location, are spread across a roughly circular area whose radius is directly proportional to the width of the sensors belonging to each particular channel. This choice allows the consideration of each channel as a space-invariant filter acting upon a limited region of the visual field. On the other hand, Wilson and Bergen (1979) and Watson (1983) consider what we will call 'anisoplanatic channels', whose sensors are spread across the whole...
visual field with a point weighting function that gets larger with increasing eccentricity. There is no escape from treating these channels as space-variant filters. Despite these differences between both channel types, they are structurally equivalent since, considering all channels simultaneously, all sensors cover approximately the same area in the eccentricity-width space, as shown in Fig. 1. From a functional point of view,

Figure 1. (a) Sensor width as a function of its visual field location for every spatial-frequency channel (disregarding orientation and phase selectivities) in Watson's (1983) model. Each symbol represents a sensor and the solid lines connect all sensors belonging to the same channel. Note that, beyond a critical limit, sensors with width less than a given size (which increases with eccentricity) do not exist, just as in Koenderink and van Doorn's (1978) model. (b) The width of extrafoveal sensors has been rounded to the nearest foveal width to convert the original anisoplanatic channels into the spatially limited format. Note that both formats are similar as regards functional space-variance.