An Active Resistor Mesh for Image Processing Based on Cortical Perceptual Processing

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To extract information relevant to movement or action it is fundamental that low-level visual processes can be performed in real time. Thus, analog hardware devices, with embedded image sensing, are of great interest in machine vision. In such devices, information, indeed, is really distributed, being mapped directly in the electrical variables, and computation is carried out massively in parallel with high efficiency and speed.

Recently, the architecture of an active resistive mesh containing both positive and negative resistors to implement a Gaussian convolution in 2D has been described [1]. The mesh consists of a 2D hexagonal or rectangular array of passive resistors connected to nearest neighbors and active resistors (negative values) connected to second nearest neighbors. The response of the network to an impulse injected at an inner node is *bell-shaped* for the presence of negative resistors. Thus the network can be used at the lowest level of image processing for the smoothing of visual data.

The tasks we would like to accomplish in this work are 1) to map from the original pattern of light intensities to intermediate abstract representation by means of appropriate receptive fields and 2) to arrange information in functional mappings apt to help all subsequent processes to come up with useful image descriptors. In doing so, we characterized our resistor mesh by the presence of extra positive resistors. These resistors make the network anisotropic and the shape of the voltage response loses its circular symmetry assuming an elongated form along the specific corresponding directions. The superimposing of clustered inhibitory connections (negative resistors) leads to a further improvement in the selectivity of the resultant receptive fields. The Gabor-like profiles of the resulting operators resemble the receptive field profiles of a wide class of cortical neurons [2].

In mammalian visual cortex, these orientation-sensitive neurons exhibit a very regular organization, which is referred to as the orientation map. In a discrete model, the orientation map is defined as a 2D array in which every node is associated with a preferred orientation ranging from 0 to π radians [3]. Such orientation maps allow the fusion of information from different channels.

In order to design resistive networks that resemble the structure of real continuous varying orientation maps, we varied the pattern of interconnections of the resistor mesh in a continuous fashion. In this way, the voltage response of the network to a current impulse at a node presents anisotropic Gabor-like shapes with orientations varying from node to node in accordance to the orientation map. Following the rules governing the design of these maps, the resistor mesh, through local interconnections, can combine a limited set of operators sufficient to cover a wide range of features, and achieve functional interactions among the operators themselves.

Our network is able to detect texture differences in an image by different responses of cells selective to different orientations, as other networks based on biological considerations do [4]. Indeed, if the test image is composed of repeated oriented elements, the cells in the regions of the map selective to that orientation have the strongest output. The testing of the network performance with synthetic and natural textured images, showed that different texture structures correspond to different patterns of excitation on the cortical map.

The active resistor network presented in this paper, provides an efficient hardware solution to real-time low-level visual tasks. The topology of the network allows, indeed, an efficient feature extraction and image representation, and also provides an effective solution for subsequent local symbolic interactions, particularly useful for texture segregation.

References

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