Integrated multi-scale architecture of the cortex with application to computer vision

Abstract

The main goal of this thesis is to try to understand the functioning of the visual cortex through the development of computational models. In the input layer V1 of the visual cortex there are simple, complex and end-stopped cells. These provide a multi-scale representation of objects and scene in terms of lines, edges and keypoints. In this thesis we combine recent progress concerning the development of computational models of these and other cells with processes in higher cortical areas V2 and V4 etc. Three pertinent challenges are discussed: (i) object recognition embedded in a cortical architecture; (ii) brightness perception, and (iii) painterly rendering based on human vision. Specific aspects are Focus-of-Attention by means of keypoint-based saliency maps, the dynamic routing of features from V1 through higher cortical areas in order to obtain translation, rotation and size invariance, and the construction of normalized object templates with canonical views in visual memory. Our simulations show that the multi-scale representations can be integrated into a cortical architecture in order to model subsequent processing steps: from segregation, via different categorization levels, until final object recognition is obtained. As for real cortical processing, the system starts with coarse-scale information, refines categorization by using medium-scale information, and employs all scales in recognition. We also show that a 2D brightness model can be based on the multi-scale symbolic representation of lines and edges, with an additional low-pass channel and nonlinear amplitude transfer functions, such that object recognition and brightness perception are combined processes based on the same information. The brightness model can predict many different effects such as Mach bands, grating induction, the Craik-O'Brien-Cornsweet illusion and brightness induction, i.e. the opposite effects of assimilation (White effect) and simultaneous brightness contrast. Finally, a novel application is introduced: painterly rendering has been linked to computer vision, but we propose to link it to human vision because perception and painting are two processes which are strongly interwoven.

KEYWORDS: Visual cortex, Focus-of-Attention, categorization, recognition, brightness, rendering.