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A neural mechanism for robust junction representation in the visual cortex

Thorsten Hansen, Heiko Neumann
Univ. Ulm, Dept. of Neural Information Processing, D-89069 Ulm, Germany
(hansen,hneumann)@neuro.informatik.uni-ulm.de

Junctions provide important cues in various visual tasks, such as determination of occlusion relationship for figure-ground separation, transparency perception, and object recognition, among others. Corners and junctions are relatively rare events in an image, carrying high information content, and are invariant against moderate changes in viewing direction and viewing distance. In computer vision, junctions are used in a number of tasks like point matching for image tracking, or scene analysis. A number of computational approaches have been proposed for the direct detection of junctions based on, e.g., parametric models [4], Gaussian curvature [5] or the structure tensor [1, 3].

In contrast to such schemes we propose a biologically motivated approach to junction representation. In this model, junctions are implicitly characterized by high activity for multiple orientations within a cortical hypercolumn. A local evaluation of orientational variance is suggested to extract junction points from this distributed representation. Initial orientation measurements are often fragmented and noisy. In previous work we have developed a model of recurrent colinear long-range interaction for contour enhancement [2]. In the model, local oriented contrast estimates which are consistent within a more global context are enhanced, while inconsistent activities are suppressed. Here we use the same representation for the purpose of junction detection.

Sim. I: feedforward vs. recurrent processing **Sim. II: ROC analysis**

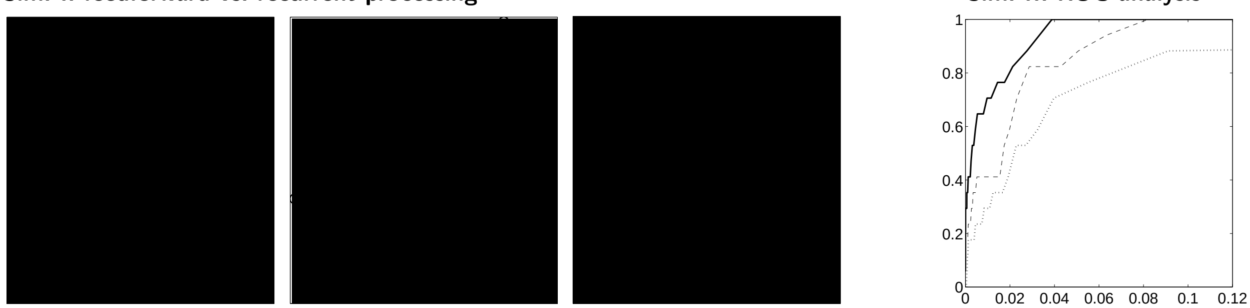

Fig. 1: Evaluation of the newly proposed junction detection scheme. *Sim. I:* Junction detection for a cube image *(left)* based on feedforward complex cell responses *(middle)*. Using recurrent long-range processing *(right)*, several false positive responses are eliminated. *Sim. II:* ROC evaluation of detection performance for the new approach *(solid line)* compared to approaches based on Gaussian curvature *(dashed)* or the structure tensor *(dotted)*, showing a superior performance of the new approach.

In a first set of simulations, we compare the detected junctions based on recurrent long-range responses to junction responses as obtained for a purely feedforward model of complex cells (Fig. 1, Sim. I). We show for a number of artificial and natural images that localization accuracy and positive correctness is improved by recurrent long-range interaction in comparison to initial feedforward complex cell processing. In a second set of simulations, we compare the new scheme with two widely used junction detector schemes in computer vision, based on Gaussian curvature and the structure tensor. Receiver operator characteristic (ROC) analysis is used for a threshold-free evaluation of the different approaches (Fig. 1, Sim. II). We show for both artificial and natural images that the new approach performs superior to the standard schemes.

To conclude, we have shown that junctions can be robustly and reliably represented by a suggested biological mechanism based on a distributed hypercolumnar representation and recurrent colinear long-range interactions.

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