Presentation Abstract

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Abstract: Humans are very efficient in detecting even jittered or partly occluded contours. But which mechanisms are capable of explaining this ability? A large class of contour integration models employs a so-called association field (AF), which reflects the connection structure between neuronal units representing different edge elements, for linking localized edges to a global contour. Here we investigate systematically how such an AF should be constructed to explain psychophysical contour detection data, combining ideas from theory, experiment and natural image statistics.
One assumption is that the brain uses a connection topology which is learned from visual experience and hence might be adapted to the statistical structure of natural images. For example, Geisler et al. (2001) measured how often one finds a pair of edge elements with a certain distance, difference in orientation and in a certain direction from each other in natural images, and how often these edge elements occur within human-labeled contours. Thus an ideal observer model, which is optimized for natural images, would use the probability that two edge elements in natural images are grouped as connection structure. Furthermore it would require unidirectional lateral interactions, linking orientation columns in only one direction, in order to obtain optimal contour detection performance. On the other hand it is often assumed that long-range horizontal axons mediate contour integration. These connections are isotropic, suggesting a bidirectional AF, symmetrically linking orientation columns on both sides in cortical space.
We tested several AFs of different symmetry and geometry in a Bayesian

contour integration model, comparing it to human contour detection. Our psychophysical experiments revealed that correlations between human decisions are much higher than expected from their detection performances alone. This suggests that different humans make identical errors, voting for the same illusory contours in the stimulus. These correlations increase with stimulus presentation time. Taking this evidence as a benchmark, we require our contour integration model to reach human performance, and in addition to reproduce the correlations and their characteristic time course. From all the AF choices we explored, the unidirectional connection structure extracted from natural image statistics by Geisler et al. explains human contour integration best. It reproduces not only human performance but also accounts for human correlations including their characteristic time course. From this we conclude that the human visual system is optimized for recognizing contours in natural images.

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