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A biologically inspired algorithm to deal with filter-overlap in retinal models

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Introduction

A multi-filter LN retinal model to simulate parallel processing by a population of retinal ganglion cells was proposed in [1] to test rank-order codes [2], a spike-latency based neural code. Dealing with filter-overlap in this model has been an area of concern [3,4]. This is because data redundancy induced by over-sampling of a point in space affects the quantity of salient information during rapid information transmission [5]. We propose a Filter-overlap Correction algorithm (FoCal) to deal with this problem of over-sampled data. The algorithm is based on the lateral inhibition technique [6] used by sensory neurons to deal with data redundancy [7], so that only salient information is transmitted through the optic-nerve bottleneck for rapid object detection and recognition.

Following the seminal work in [6] on lateral inhibition, mutual inhibition was described quantitatively in [8] as

$$r_1 = e_1 - K_{1,2}(r_2 - r_{1,2}^0) \quad r_2 = e_2 - K_{2,1}(r_1 - r_{2,1}^0),$$

where r is the response of a receptor unit, e is the excitation supplied by the external stimulus on the receptor, K is the coefficient of inhibitory influence of one receptor over the other, and r^0 is the threshold frequency. Let Φ_1 and Φ_2 be two filters sampling an image at spatial locations (x, y) and $(x+1, y)$ respectively on a digital raster, the respective coefficients of filtering c_1 and c_2 representing the spiking latency of the retinal ganglion cells corresponding to the filters. The filter overlap is written as $O_{1,2} = O_{2,1} = \langle \Phi_1, \Phi_2 \rangle$. Let $c_1 > c_2$. The smaller coefficient is corrected for the effect of this overlap thus

$$r_2 = c_2 - O_{2,1} \cdot c_1,$$

where r_2 simulates the overlap corrected response latency of the ganglion cell corresponding to Φ_2. However, we introduce lateral inhibition post-spiking whereas it is pre-spiking in biology. Thus, we substitute the stimulus strength e_2 with the corresponding coefficient of filtering c_2. The threshold frequency is also irrelevant in our case. Further, we implement a winner-take-all mechanism in each iteration of the algorithm: the largest coefficient inhibits all others, the degree of inhibition being proportional to O, which corresponds to K. This reduces redundancy in the coefficient set and helps prioritise salient information, thus enabling rapid recovery of perceptually important information [4] in rank-order encoded images.

Results and conclusion

Using a data set of 65 images, we obtain the mean perceptually-important information recovery plot as shown (Figure 1). The error-bars show the standard deviation across the data set. We observe an increase of more than 20% in the total information recovered. Moreover, the rate of information recovery is much faster, with 80% recovery using the top 10% of the coefficients, which is a 30% increase compared to rank-order encoding without using FoCal. Based on these results, we argue that FoCal pro-

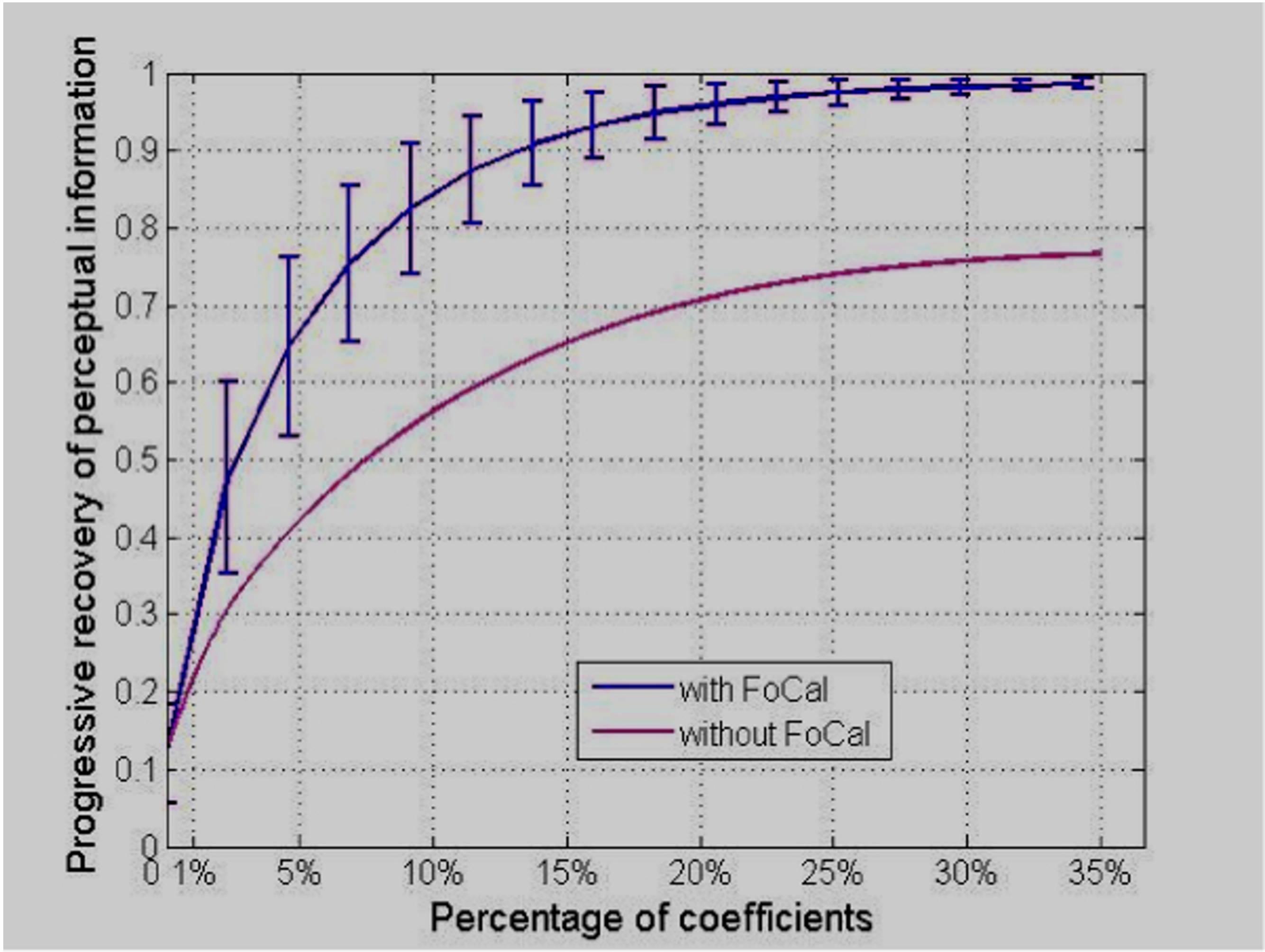

Figure 1

vides a general method for coping with non-orthogonal basis functions for current and future biologically inspired visual models.

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