Cortical Under-Sampling and Crowding

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Crowding

Crowding is the term used to describe the negative effect of nearby patterns on the identifiability of patterns in peripheral vision. When the top line of letters is viewed peripherally, the middle letter is clear, but can be difficult to identify when closely surrounded. Crowding has been the focus of many recent studies and the subject of a recent special issue (Pelli, Cavanagh, Desimone, Tjan, and Treisman, 2007).

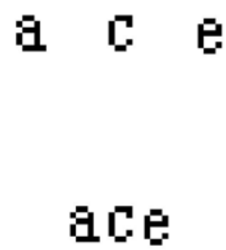

Figure 1. Spaced and crowded letters.

Cortical Under-Sampling

The cortical magnification theory of peripheral vision proposed that peripheral processing was a scaled version of central processing, scaled by the ganglion cell density (Rovamo and Virsu, 1979; Beard, Levi, and Klein, 1997). Aliasing would be expected to occur in the periphery from cone under-sampling and ganglion cell under-sampling (Smith and Cass, 1987; Thibos et al., 1987; Henrickson, 2004). These aliasing effects would be expected to be small and local and not important when the scale of the stimuli is increased to make isolated peripheral identification comparable to central. Aliasing in the cortical domain can spread out in space. Here we consider random cortical under-sampling as a possible contributor to crowding.

A Cortex Transform Model

1) The image is filtered by a version of the Cortex Transform (Watson, 1987).
2) The space domain images, representing the cortical cells, are randomly sampled by one of the three methods described below.
3) The image is reconstructed by a) filtering by the corresponding channel filter and then b) adding up all the channels.

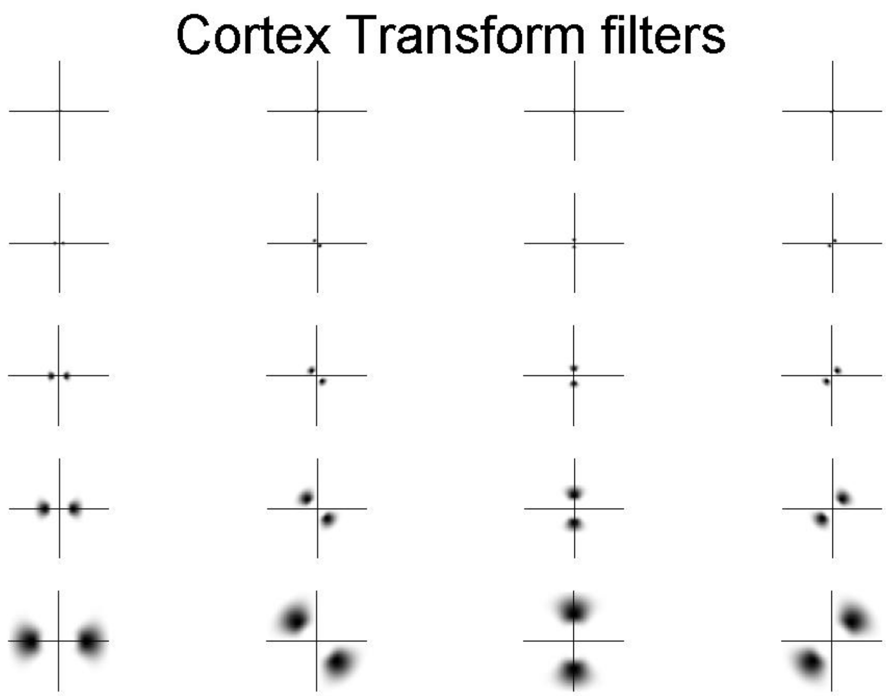

Figure 2. The Cortex Transform filters in the frequency domain.

Sampling Methods

Method 0: Constant sampling at 10%.

Method 1: High frequency channels sampled at 12.5%; next lower frequency channels at 6.25%, etc. (Average = 4.8%)

Method 2: High frequency channels sampled at 25%; next lower frequency channels at 6.25%, etc. (Average = 6.7%. Optimal expected sampling numbers, but random.)

Results

The reconstructed images of an impulse are shown in Figure 3. The impulse is degraded without sampling by the loss of the low and high frequency residues and the imperfect reconstruction of the transform by itself. The sampling does generate spatial noise around the impulse. The reconstructed under-sampled letter images appear in Figure 4. Nearby letters do not appear to have any striking effect on the letter shape, but there are hints of disruptive features, especially for methods 1 and 2.

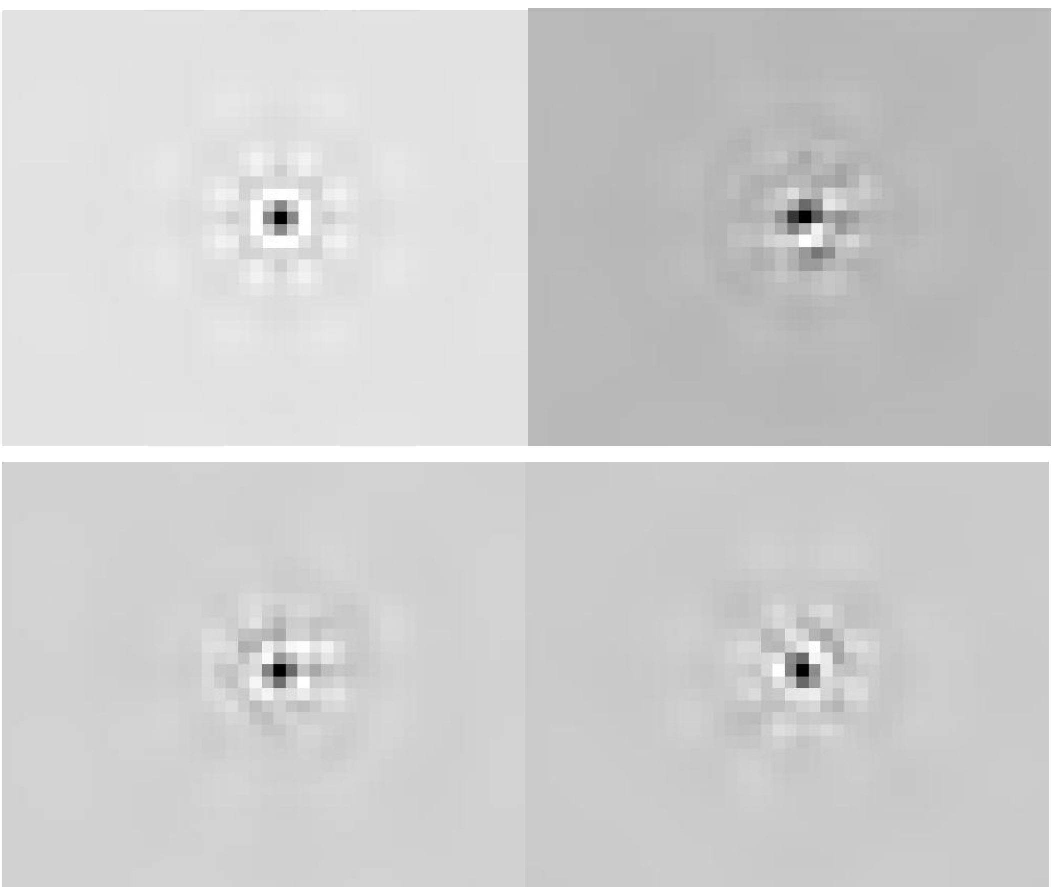

Figure 3. The effect of cortical sub-sampling on an impulse. Upper left: no sampling. Upper right: method 0. Lower left: method 1. Lower right: method 2.

Figure 4. The effect of cortical sub-sampling on the letter image. Sampling as in Figure 3.

Discussion

Random cortical under-sampling leads to a failure of translation invariance in the image representation. However, since the cone and ganglion cell images already generate aliasing that would make translation invariant calibration difficult (Tabernero and Ahumada, 1992), translation invariance may not be a feature of the periphery.

Random, rather than predictable, sub-sampling may be preferable for keeping all features potentially visible.

Strong peripheral inhibitory processes (Xing and Heeger, 2000; Xing, 2002) may be needed to remove the sampling effects, and may then contribute to the crowding effects.

References

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