Emergence of motion-in-depth selectivity in the visual cortex: An evidence of phase-based second-order motion mechanisms?

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The question of which mechanisms are responsible for second-order motion perception has an important bearing on the issue of whether the brain adopts a specialized second-order (non-Fourier) motion channel or relies upon the hierarchical combination of the motion signals conveyed by the first-order (Fourier) channel (Chubb and Sperling, 1988 J. Opt. Soc. Am. A 5 1986-2006).
We propose and analyze a type of second-order motion computation in which motion energy mechanism is applied to a population of disparity-tuned units (cf. V1 cells, Ohzawa et al, 1997 J. Neurophysiol. 77 2879-2909) to compute motion toward-to/away-from the observer.
We demonstrate that binocular energy complex cells relay phase temporal derivative components that can be combined, at a higher level, to yield a specific motion-in-depth (MID) selectivity. The rationale of this statement relies upon analytical considerations on phase-based dynamic stereopsis, as a time extension of the well-known phase-based techniques for disparity estimation (Fleet et al, 1991 CVGIP: Image Understanding 53 198-210).
On this basis, an architectural cortical model for MID selectivity in the visual cortex is proposed.
By hierarchical combinations of the same signals provided by spatio-temporal frequency channels, the resulting cortical units actively eliminate sensitivity to a selected set of parameters, thus becoming specifically tuned to different features, such as disparity but not MID, or MID but not disparity.
The emergence of MID tuning is pointed out in relation to the unbalanced ocular dominance of the afferent binocular contributions.