GIBSON, MEET TOPOGRAPHY: THE DIPOLE STRUCTURE OF THE VISUAL FIELD IS CRUCIAL TO A ROBUST ESTIMATE OF NAVIGATION BY OPTICAL FLOW*†

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Abstract

Gibson's sketch of a bird flying through a spherical vector field containing a *source* (frontwards) and a *sink* (rearwards) of the optical flow sparked the beginning of interest in optical flow as a navigational cue. He claimed "the anatomical fact of an approximate 'wiring system' from retina to brain has nothing to do with perception", an opinion which some still hold. The source and sink lie along the direction of motion, but the sink is apparently uncomputable—it lies beyond the limits of the visual field. However, recent advances in understanding visuotopic mapping (the *dipole model*; see Polimeni et al., *VSS 2005 Annual Meeting*) indicate the existence of both a foveal source and a peripheral sink in the cortical representation of optical flow field that is realizable in the retinal and cortical representations. The dipole geometry of topographic mappings provides accurate cues for navigation and egomotion estimation which solve several of the problems which have plagued earlier attempts that ignored peripheral vision. Specifically, the peripheral flow (i) is tolerant of misalignment of the optical and motion axes; (ii) is insensitive to significant occlusion by distractors of unknown motion; and (iii) represents an accurate model of wide-field visuotopy. This algorithm is based on the Helmholtz-Hodge decomposition of the optical flow field, and the basic measurements are given by the divergence and curl operations on the cortical representation of the vector field. We demonstrate its advantages using synthetic optical flow fields as well as natural image sequences obtained from high resolution wide-field natural movie sequences. It is the peripheral rather than the foveal structure of the optical flow field that provides the most robust estimate of egomotion, particularly when the peripheral field is represented in terms of a (negative) logarithmic pole in addition to the familiar (positive) logarithmic pole at the fovea, as in the dipole model of cortical visuotopic mapping.

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