A Space-Variant Model for Motion Interpretation across the Visual Field

Guido Maiello[1,2,3], Manuela Chessa[2], Peter J Bex[3], Fabio Solari[2]

[1]UCL Institute of Ophthalmology, University College London, London, UK

[2]Dept. of Informatics, Bioengineering, Robotics and System Engineering, University of Genoa, Genoa, Italy

[3]Dept. of Psychology, Northeastern University, Boston, MA, USA

We examine the role of central and peripheral vision in the dorsal visual pathway for the processing of self-motion and of object motion. [Bex and Falkenberg, 2006] showed that the accuracy with which human observers can estimate the focus of radial motion (FRM) in random dot stimuli decreases as a function of retinal eccentricity and, using equivalent noise analysis, that this effect is due to an increase in local motion detector noise rather than undersampling. We aim to model the processes of direction detection and motion pooling that support the perception of optic flow, and to understand how optic flow computation changes across the visual field. We implement a neural model for the estimation of the FRM at different retinal locations and we assess the model by comparing its results with respect to the precision with which human observers can estimate the FRM in naturalistic, moving dead leaves stimuli. The proposed neural model describes the deep hierarchy of the first stages of the dorsal visual pathway [Solari et al., 2014]. Such a model (see Fig. 1) is space-variant, since it takes into account the retino-cortical transformation of the primate visual system through log-polar mapping that produces a cortical representation of the visual signal to the retina. The log-polar transform of the retinal image is the input to the cortical motion estimation stage where optic flow is computed by a three-layer population of cells. A population of spatio-temporal oriented Gabor filters approximates the simple cells of area V1 (first layer), which are combined into complex cells as motion energy units (second layer). The responses of the complex cells are pooled (third layer) to encode the magnitude and direction of velocities as in the extrastriate motion pathway between area MT and MST. The sensitivity to complex motion patterns that has been found in area MST is modeled through a population of adaptive templates, and from the responses of such a population the first order description of optic flow is derived. Information about self-motion (e.g. direction of heading) is estimated by combining such first-order descriptors computed in the cortical domain. The model shows qualitatively similar patterns of results to the human behavioral data and captures the essential aspects of the neural computations that occur in the cortical motion pathway. Our work has clear applications in neuromimetic robotic architectures and, more broadly, we provide a framework in which to model complex motion integration across the visual field.

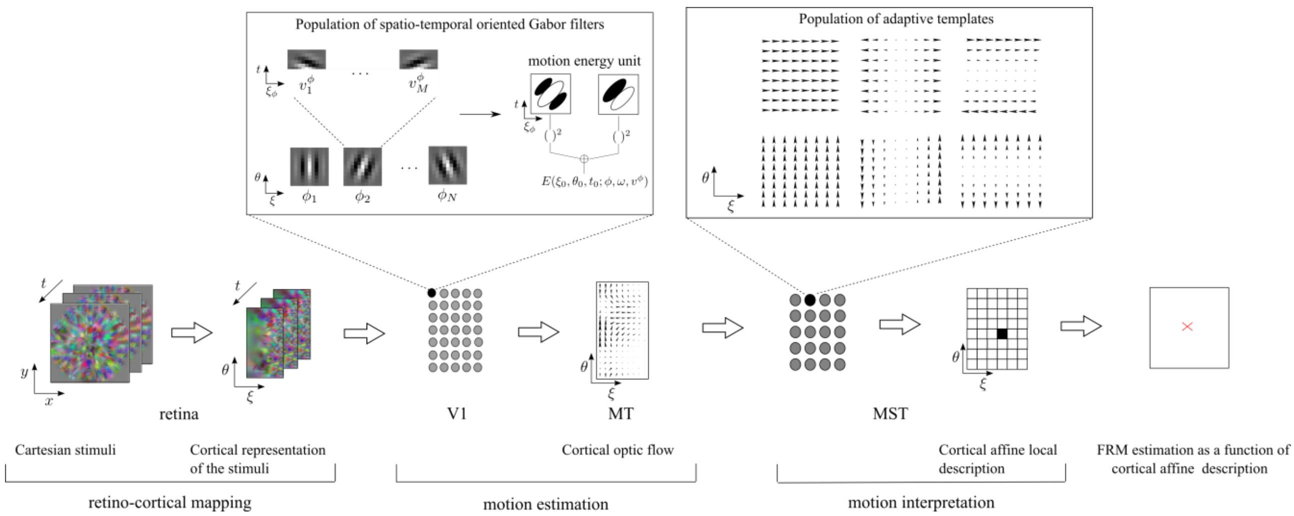

Figure 1. The neural space-variant model.