ABSTRACT

A Neurophysiology Model that Makes Quantifiable Predictions of Geometric Visual Illusions

This thesis is focused on modelling low-level vision and the encoding of visual input by the simple retinal cells.

The study of human vision is a 'multidisciplinary field', connecting the physiology of vision to bioplausible computational modelling, as well as psychophysical experiments with real subjects. One source of evidence about vision is optical illusions, which do not necessarily occur in a computer vision (CV) model, but should be apparent in a vision model that claims to represent the way human vision works, or a vision system that tries to identify the same patterns and features that a human would. This area of research leads to a shibboleth for testing bioplausible models of vision. The goal of this PhD research is to describe, simulate and quantify a bioplausible model that reflects differences in the dominant tilts apparent in a family of Geometrical Illusions.

In this dissertation, a neurophysiologically inspired model has been developed, implementing the lateral inhibition of the retinal cells based on Gaussians (Mexican Hat) filtering at multiple scales. Our model produces Difference of Gaussian (DoG) at different scales as a bioplausible representation of the image and interprets them as edge maps at multiple scales. The edge map is further investigated using an analytic processing pipeline in Hough space to quantify the angle of tilt emergent in the model around four reference orientations (-45°, 0°, 45°, 90°). In this study, a quantifiable prediction is developed for the degree of perceived tilt in the Café Wall pattern, a typical Geometric Illusion, in which the mortar between the tiles seems to converge and diverge. The model also predicts different perceived tilts in different areas of the fovea and periphery as the eye saccades to different parts of the image. Several sampling sizes and aspect ratios, modelling variant foveal views, are investigated across multiple scales in order to provide confidence intervals around the predicted tilts, and to contrast local tilt detection with a global average across the whole Café Wall image. Beyond the Café Wall illusion, the model has been applied to investigate local tilt for a more general class of complex Tile illusions such as Complex Bulge pattern and Spiral Café Wall.

This is the first model to provide verifiable quantitative predictions of the tilt perceived across a range of "Café Wall" illusions. More formally, we have shown that a simple Difference of Gaussian Classical Receptive Field model, implementing multiscale responses of a symmetrical ON-center and OFF-surround Retinal Ganglion Cells (RGCs), can easily reveal the emergence of tilt in these patterns. We hypothesize that in later stages of perception, these local tilt cues are integrated by more complex cortical cells.