

Visual Depth Perception from Motion Parallax and Optic Flow

Suppose you are riding in a car looking out the side window. You see a farm house in the distance and as you watch the dog on the front porch, you notice that the trees behind the house seem to move with you, while the mailbox in front of the house moves opposite your direction of motion. This phenomenon is called "motion parallax." The motion gives a visual cue to the relative depth of the objects in the scene, but the understanding of the geometry of the perceptual cues has only recently been revealed.

Optic flow is another retinal motion phenomenon that everyone is familiar with from movies like, "Star Trek." The captain calls for "warp drive" and the stars stream past on the window of the space ship - like the flow on the surface of a river. This visual process has been studied a lot for humans and computer vision. This project will explore the mathematics of how these two different geometric inputs to vision might contribute to human perception and computer vision.

Suppose you are riding in a car looking out the side window. You see a farm house in the distance and as you watch the dog on the front porch, you notice that the trees behind the house seem to move with you, while the mailbox in front of the house moves opposite your direction of motion. This phenomenon is called "motion parallax" and it has long been known that objects move on your retina because of your changing position. The motion gives a visual cue to the relative depth of the objects in the scene, but the understanding of the geometry of the perceptual cues has only recently been revealed and there is still much to discover.

An article by J.W. Nadler, D.E. Angelaki, & G. C. DeAngelis (Nature 2008) showed that an extra-retinal signal is neurologically needed to perceive depth. Just before that appeared, a vision scientist, Mark Nawrot of North Dakota State U, and I found a mathematical formula for depth in terms of the ratio of the retinal motion rate over the smooth pursuit eye-tracking rate. We also reported on two psychophysical studies that suggest that people use the motion/pursuit ratio in judging depth. (Published in Vision Res. 49, p.1969-1978 (2009).) Most recently, Nadler, Nawrot, Angelaki, and DeAngelis, showed that the brain uses the smooth eye pursuit signal in depth perception (Neuron 2009).

What this all means is: Your visual attention of the cute dog on the front porch makes your eyes turn to maintain "fixation" on the object of primary interest - at least for a while. This "smooth pursuit" is used in conjunction with the retinal motion in your brain to give your perception of the depth of the trees and mailbox. Without that extra-retinal signal, your brain can't even determine "near and far" in the lateral motion case.

Optic flow is another retinal motion phenomenon that everyone is familiar with from movies like, "Star Trek." The captain calls for "warp drive" and the stars stream past on the window of the space ship - like the flow on the surface of a river. This is a retinal motion that is seen without "smooth pursuit" so different neural mechanisms are used to construct a mental image of the 3D scene. This visual process has been studied a lot for humans and computer vision, but the 1925 edition of the treatise on vision by Helmholtz said, "...the probability is that both of them generally contribute to the result in some way, although it would be hard to say exactly how." Is

the "last word" on this because we only recently learned how smooth pursuit contributes to depth perception.

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