

A Snake's Perspective on Heat: How to Reconstruct Imperfect Detection of Infrared Radiation

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Author Summary of Paper Y26.3
Friday, March 17, 2006, 8:24 AM, Room 323; 2006 APS March Meeting

In our study we focus on the infrared-sensitive pit organs of snakes. Since the aperture of the “pinhole” admitting the heat is wide (about 1 mm or more; see the figure) so as to allow enough energy per second and hence detection of a moving target, such as running mice, its mapping properties are just poor and the resulting image is highly blurred. With many snakes being able to hit a target rather precisely the question then is: How do they manage? That is, how does their system of nerve cells manage?



Figure 1: Two groups of snakes, pythons and crotalines, possess heat-sensitive organs. Crotalines, such as rattlesnakes, possess one pair of pit organs, located between the nostrils and the eyes, as shown in this image. In pythons, which we do not consider here, an array of organs is distributed along the upper and lower lips of the animal. Photograph courtesy of Guido Westhoff (Bonn).

From a biophysicist's point of view, for any animal sensory system the goal is to identify a set of detectors, such as the above pit organs, and to understand how the animal makes measurements with it, i.e., how it detects the heat coming in, and how it reconstructs the values, and hence the image, of some physical quantity of interest, such as a heat distribution of a warm-blooded prey. In many cases there will be a one-to-one mapping between the value of the physical parameters that need to be determined and the response of the detector system. If, however, the information transmission is incomplete or contains considerable noise, reconstruction may turn out to be nontrivial.

We develop a general mathematical model, called *the virtual lens*, that allows for reconstruction of input to a detector system, if the physics underlying the interaction between the input and the detector system is both known and linear. The model is highly efficient, not limited to sensory biology, and can be applied to engineering problems as well. Though the snake's neuronal information processing has not been completely clarified yet, we can explain several salient aspects such as the receptive field of neurons in the *optic tectum*, which is that part of the brain where the visual map originating from the eyes and the infrared map originating from the pit organs are so-to-speak merged.