Talk 3.1

Optimal Computation of Flow Field Variables from Natural Visual Signals

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The overall goal of this project is to characterize quantitatively the extraction of wide-field motion estimates from a natural visual input data stream. The project has three distinct phases:

1. Construct a camera/gyrosensor combination that measures visual input and camera rotation in a natural environment, in a way that is representative for blowfly vision.
2. Analyze the appropriate conditional distributions of camera and gyrosensor data, sampled outside, and derive optimal motion estimators for a variety of conditions.
3. Compare the characteristics of the optimal estimator to those of motion estimation in the blowfly visual system by replaying suitably modified versions of the sampled data.

Phase 1 is nearing completion. The camera consists of a 61 pixel hexagonal array of optical fibers that sample light intensities from a holographic diffuser in the focal plane of an f=50 mm lens. Array spacing and fiber-diffuser distance are chosen to match the sampling raster and the point spread function of photoreceptors in the fly's retina. However, the optics and electronics are designed to have far greater photon capture efficiency than fly photoreceptors. This is possible essentially because we use a lens of vastly larger diameter than the fly's compound eye lens (the ratio of diameters is roughly one thousand, and the photon capture efficiency scales with the square of that number). The fibers project to an array of photodiodes, followed by current-to-voltage converters and filters. Attached to the camera are three gyrosensors which sample rotational velocities along the yaw, pitch and roll axes. The optical and gyrosensor signals are sampled at 1 kHz through an A/D converter housed in a ruggedized laptop computer. In normal operation the camera is hand held, while the amplifiers and data taking equipment are stored in a backpack.

We plan to sample data in a variety of conditions: Different environments, different times of day, and variable illumination conditions (for example overcast sky and bright sunlight). In analyzing the sampled data we titrate the effective amount of photon shot noise by adding random fluctuations to the sampled data. We can do this, first because our raw measurements have very high photon efficiency, and second because the statistics of photon shot noise are very well understood. In this way we will be able to characterize optimal motion estimation in different environmental conditions, and for different overall effective light intensities.

The results from the analysis just described will be compared to the results from experiments on the blowfly, where we record from lobula plate tangential cells that encode wide field motion. In these experiments the fly will be stimulated by a 61 element

LED array, which is under construction. This allows us to study optimal motion estimation and biological motion estimation in comparable ways, and under a very wide set of conditions.

PI Website

http://www.physics.indiana.edu/faculty/DeRuyter.shtml