“The Whole Rat Catalog” – relating form and function in the rat vibrissal array

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When a rat ‘whisks’ against an object, different whiskers, each with different shapes and mechanical properties, contact different parts of the object, either simultaneously, or with varying time delays [1]. Thus, a complete understanding of how form and function are related in the vibrissal array must include a detailed knowledge of the spatio-temporal sequence of sensory input across the array. Our long term goal is to obtain the spatiotemporal patterns of sensory input that result from the rat’s natural exploratory behaviors. With current video techniques, this goal is virtually impossible, because each whisker must be tracked individually. The goal is more realistic if the position and velocity of the head and a few whiskers can be fed to a computational model that “fills in” the rest of the array. As a first step towards this objective we have constructed “The Whole Rat Catalog” (WRC), a complete 3-dimensional (3D) model of the rat head that includes the positions, shapes, and orientations of the whiskers.

Whiskers were plucked from four female Sprague-Dawley rats and scanned using a standard flatbed scanner. To the eye, the majority of the vibrissae appeared to lie flat in a plane. However, a closer inspection revealed that many of the whiskers actually had a small amount of curvature out of the plane. It was found that typically, the proximal 70-80% of the length of the whisker lay in a plane, while the most distal 20 – 30 % curved slightly out of the plane. A coordinate-free or parametric representation of the whisker shape was then employed in order to describe the 2D shape without reference to Cartesian coordinates. In a coordinate-free representation of a plane curve, the shape of the curve is described by specifying the curvature $\kappa(s)$, at each point, as a function of the arc length $s$. In the absence of any a priori model for $\kappa(s)$, we assumed a quadratic form: $\kappa(s) = ax^2 + bs + c$. We obtained excellent fits to the data by this method. A very strong correlation was found between the coefficients, and to a very good approximation, $b = -a$, and $c = 1 + 0.2b$.

To determine the three-dimensional (3D) position and orientation of each vibrissa on the rat's head, a high resolution volumetric scan of the head and whisker array was obtained with a 3D laser scanner. The 3D whisker orientation was then quantified by matching the 2D scan data with the corresponding 3D volumetric data. The 3D orientation of the whiskers could be defined using three angles: $\theta$ (rostral-caudal), $\phi$ (dorsal-ventral), and $\psi$ (rotational). All three orientation angles were found to vary smoothly across the array. In the WRC, we have measured 17 different parameters relating to the position and orientation of the whiskers on the mystacial pad. We examined correlations between all non-identical pairs of these parameters. For four pairs, we observed “strong” correlations, i.e. with $|r| > 0.8$, which are described in our poster. In future work, we plan to insert realistic whisker dynamics into this model.

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References