Cosine Tuning Used in Neuro Decoding

2018-09-19

0.1 Goals

- Are there any relations of single neuron activity to the direction of movement?
- Does individual cells in the motor cortex have a preferred direction of movement?
- If so, can we quantify the relations with a distribution?
- How do we decode that from neural recordings?
- What's the significance of cosine tuning?

0.2 A brief history

In 1968, Evarts observed the activity of single cells in the motor cortex of the monkey performing push-pull movements. He made pioneer discovery on relating cortical cells in the arm-related area to the movements. and to the muscular force generated by the animal.

Neuronal activity in the primate motor cortex can be related to the force exerted, to the direction, or to the velocity of the movement, alone or in combination. Of the three, the relations to the direction of the movement have been least well analyzed.

Previous studies utilized only two opposite directions in their experiments. So in 1982, Georgopoulos has thus performed an 8-direction study to examine the relations of single neuron activity to the direction of movement.[1]

0.3 Experimental set up

In his paper,. . . . . . .

[1] A. P. Georgopoulos, J. F. Kalaska: R. Caminiti, and J. T. Massey. "on The Relations Between The Direction Of Two-dimensional Arm Movements And Cell Discharge In Primate Motor Cortex." The Journal of Neuroscience, Vol. 2, No. 11, pp. 1527-1537. 1982

0.4 Analysis using first degree periodic (sinusoidal) regression

let

$$y_i$$

(

$$i = 1, 2, ..., 8$$

) be the mean rate when a cell discharges during movements towards direction

$$\theta_i = 0, 45, 90, ..., 315°$$

, respectively. We can fit a regress with

$$y = b_0 + b_1 sin\theta + b_2 cos\theta$$

or alternatively,

$$y = b_0 + \sqrt{b_1^2 + b_2^2} cos(\theta - \theta_0)$$

where

$$b_0, b_1, b_2$$

are regression coefficients that can be estimated with the least square unbiased estimators

$$b_0 = \bar{y} = 1/8(y_1 + y_2 + y_3 + ...y_8)$$

$$b_1 = 1/4[\frac{1}{\sqrt{2}}(y_2 + y_4 - y_6 - y_8) + (y_3 - y_7)]$$

$$b_2 = 1/4[\frac{1}{\sqrt{2}}(y_2 - y_4 - y_6 + y_8) + (y_1 - y_5)]$$

and

$$\theta_0$$

is the preferred direction. Using trigonometric moments, we can calculate

$$\theta_0$$

by first defining

$$\theta_0' = tan^{-1}\frac{b_1}{b_2}; -45° < \theta_0\prime < 45°$$

According to the quadrant,

$$\theta_0$$

is given by

$$\theta_0 = \theta_0' if b_1 > 0, b_2 > 0 \theta_0 = \theta_0' + 180^\circ if b_2 < 0 \theta_0 = \theta_0' + 360^\circ if b_1 < 0, b_2 > 0;$$

A performance measure

$$R^2$$

can indicate how well the regression fit is.

$$R^2 = \frac{\sum \hat{y^2}}{\sum y^2} = \frac{4(b_1^2 + b_2^2)}{\sum (y - \bar{y})^2}$$

An index of the directional modulation for increase in discharge at the preferred direction over the overall mean can be expressed as

$$I = \frac{\sqrt{b_1^2 + b_2^2}}{b_0}; b_0 > 0$$

0.5 Results

606 arm-related cells were tested. 323 cells were active under the task circumstances. 296 cells have significant relations between cell discharge and the direction of movement during the total experimental time.

Directional tuning curve: 241 cells express a directional preference and 75%of them has an adequate fit with

$$R^2 \geq 0.7$$

. More cells has preferred direction of

$$45^\circ$$

than

$$225^\circ$$

.

Change of neural discharge: When the movement direction was near (further away) the cell's preferred direction, an increase in activity occurred more (less) frequently