Simultaneous Optimization of Clustering and Dimension Reduction for Neural Population Activities

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Recently, there has been an increase in the need to ‘read out’ information from the single-trial activities of many neurons. This is useful to develop brain-machine interfaces (BMI). To construct better BMI, it is critical to visualize the information that neurons encode. Clustering and dimension reduction are useful visualization methods. However, there remain two problems that we are concerned. One problem is that the dimension of population activity vectors (PVs) which consist of individual neural activities is high. The other is that the number of data is usually small because of few experimental conditions. Clustering for neural population activities has troubles in overfitting and high computational complexity. In this study, we consider a case that high-dimensional noises with large variances exist as shown in Fig.1. In this case, usual dimension reduction methods might not extract meaningful signals in a low-dimensional space. To solve these problems, we developed a new algorithm to optimize clustering and dimension reduction simultaneously. The proposed probabilistic model was a product of a mixture of two-dimensional Gaussians and 43-dimensional spherical Gaussian noises (Fig.1). Since the spherical Gaussian assumption was violated for the neural data, we applied whitening to make the variances of all components of PVs equal. To avoid enlarging the components with too small variances, we applied principal component analysis to project the PVs to 10-dimensional vectors. We estimated the parameters of the Gaussian mixture by variational Bayes (VB), and optimized basis vectors which determined a two-dimensional subspace by steepest ascent method to maximize free energy of VB. We used the activities of 45 neurons recorded individually in the monkey inferior-temporal cortex while 38 visual stimuli (geometric shapes and faces of humans and monkeys) were presented [1] as test data. A PV for each stimulus consisted of mean activities of 45 neurons within a 50-ms sliding time window. To compare the effect of the whitening, we show the 38 PVs projected into the two-dimensional subspace within 90-140 ms and 140-190 ms time windows without whitening (a) and with whitening (b). The points represent the PVs for human faces (red), monkey faces (blue), and shapes (green), respectively. The ellipses represent the resulting clusters. Although 4 clusters were assigned for monkey faces within the 140-190 ms window in (a), 3 clusters were assigned in (b). Individual clusters in (b) were separated much more clearly than (a). These results indicate our algorithm is very useful to visualize the information that many neurons encode.

Fig.1 Probabilistic model. Fig.2 Clustering results in subspaces: (a) without whitening, (b) with whitening.

References