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Change Point Detection Based on Principal Component Analysis for Multivariate Time Series with Application to Single Molecule Data

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Abstract

Change point detection has been a long-standing problem in statistical analysis. This study aims to develop a nonparametric offline scheme for detecting changes in mean and/or variance in multivariate time series. Based on the principal component analysis (PCA), the multivariate data is projected onto a lower dimensional space such that the multidimensional detection problem is reduced to a one-dimensional one. As a result, we can apply the well formulated univariate methods, namely, the cumulative sum (CUSUM) and cumulative sum of squares (CSS) methods, to test the existence of a change in mean and variance, respectively. The study shows that both methods are reliable to test the existence of a change based on the permutation test. Moreover, the CUSUM-based estimator and the mean square error (MSE) estimator are proposed to determine the most likely change point locations. We compare the performance of the estimators in a simulation study and the results show that the performance of these two estimators depends very much on the properties of data. The MSE estimator outperforms the CUSUM-based estimator if determining a change point location in a time series with a mean change. On the contrary, if determining a change point location with a variance change, the CUSUM-based estimator is preferable. Finally, the CUSUM and CSS methods are combined to detect simultaneous changes in mean and variance. The results on both simulated and real data show that the combined method complements each other well and it can successfully determine the most prominent change point location by comparing the uncertainty in identifying the change point locations.

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