A phenomenological approach to fix order of an autoregressive process and optimal spectral analysis of non-random fluctuations in a time series

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A new approach to the autoregressive (AR) analysis of a time series of non-random fluctuations under the Yule-Walker framework to make spectral estimation has been developed. The algorithm is based on the use of correlation period, averaging period and noise reduction factor, all of which are estimated from the observed time series. It has been applied to simulated data with two closely spaced frequencies (0.05 Hz apart) embedded in white noise and observed natural data of ionospheric scintillations. The algorithm is applicable in two parts. First, the correlation period inherent in the time series is treated as an information criterion, since it is a characteristic of the autoregressive process under consideration. It is referred to as the Correlation Information Criterion (CIC). The order of the autoregressive process is fixed based on the minimal estimate of correlation period. The CIC, for fixing the optimal order of the autoregressive process, is compared with some of the known criteria, such as, Akaike Information Criterion (AIC) in terms of Final Prediction Error (FPE) and Bayesian Information Criterion (BIC). In this paper an alternate Multiple Correlation Information Criterion (MIC) is also developed based on the conventional statistical multiple correlation function. It is shown in this paper that the FPE, BIC and MIC are similar in nature, as they result in similar optimal order of the autoregressive process. However, the CIC results in a better, realistic order of the autoregressive process. For instance, for the simulated data of two frequencies spaced 0.05 Hz apart embedded in white noise, all the three criteria of FPE, BIC and MIC suggest a second order autoregressive process. The CIC, however, suggests a ninth order AR process. Also, for one sample of ionospheric scintillation data, the FPE, BIC and MIC suggest a fourth order autoregressive process. The CIC suggests a seventh order autoregressive process. In another example of ionospheric scintillation data, the FPE, BIC and MIC suggest a second order or perhaps a fourth order autoregressive process. The CIC unambiguously reveals a fourth order autoregressive process. Secondly, from the parameters estimated from the observed time series including the order of autoregressive process, the spectral parameters such as signal detectability, effective signal-to-noise ratio and spectral resolution are computed. For instance, for the simulated data of two frequencies spaced 0.05 Hz apart embedded in white noise, the autoregressive scheme of ninth order (as suggested by the CIC) completely resolves the two frequencies. Likewise, for one sample of ionospheric scintillation data, the AR smoothened spectrum of seventh order (as suggested by the CIC) fits better the direct spectrum than the AR smoothened spectrum of fourth order (as suggested by the FPE, BIC and MIC). Likewise, for the other sample of ionospheric scintillation data, the AR smoothened spectrum of fourth order (as suggested by the CIC) fits better the direct spectrum than the AR smoothened spectrum of second or fourth order (as suggested by the FPE, BIC and MIC). The detailed paper discusses potential applications of the developed AR algorithm in signal processing.

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