Asymptotic statistics problems with nuisance parameters arising in processing of multidimensional geophysical time series

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Abstract

Computer data processing of multidimensional time series (MTS) is challenge in modern geophysics due to wide use of seismic recording systems involving many tens and even hundreds of seismometers. Specific feature of these random time series is strong correlations between their components. Probability model of geophysical MTS which allows to derive practically applicable data processing algorithms is the model of Gaussian stationary MTS (GSMTS). The GSMTS model of geophysical noise observations does not contradict with many investigations of real seismic noise fields The presentation is devoted to application of L. Le-Cam asymptotic decision theory for deriving computationally effective data processing algorithms for detecting seismic signals hampered by strong noise and estimating coordinates of seismic source generating these signals. The algorithms are based on asymptotically sufficient statistics (ASS) for family of probability distributions of GSMTS observations for cases when signal generated by seismic source can be regarded as one dimensional random GSTS or deterministic time series. Both these signal models involve unknown nuisance parameters.

The ASS for GSMTS depends on finite discrete Fourier Transform (FDFT) of multidimensional observations and matrix power spectral density (MPSD) of noise GSMTS. This allows online (real time) computations at the state of the art personal computers. If the noise MPSD is not a priory known it is estimated using auxiliary "pure" noise observations and computationally effective multidimensional autoregressive - moving averaged modeling of the observations. The most interesting from theoretical point of view (and important in applications) is the case when there is no any information about the signal generated by the seismic source. In this case all the signal samples must be regarded as nuisance parameters. As the number of these parameters tends to infinity with growing observations number, this problem can not be treated by L. Le–Cam asymptotic decision theory. We derived an algorithm for statistical estimation of seismic source coordinates by maximum likelihood (ML) approach based on asymptotic complex normal distribution of FDFT of multidimensional observations. This approach is some generalization of the one implemented by M. Nussbaum [Journal of multivariate analysis, 14, 1984]. Some approval of our approach is that partial derivations for source coordinates of mentioned asymptotic complex normal distribution coincide with components of ASS for the coordinates. The asymptotic covariances of the ML estimates are calculated and the problem of determination of lower bounds for regular estimates in the analyzed task is discussed.