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Bias-Corrected Estimation Methods for Receiver Operating Characteristic Surface

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Abstract : With three diagnostic categories, assessment of the performance of diagnostic tests is achieved by the analysis of the receiver operating characteristic (ROC) surface, which generalizes the ROC curve for binary diagnostic outcomes. The volume under the ROC surface (VUS) is a summary index usually employed for measuring the overall diagnostic accuracy. When the true disease status can be exactly assessed by means of a gold standard (GS) test, unbiased nonparametric estimators of the ROC surface and VUS are easily obtained. In practice, unfortunately, disease status verification via the GS test could be unavailable for all study subjects, due to the expensiveness or invasiveness of the GS test. Thus, often only a subset of patients undergoes disease verification. Statistical evaluations of diagnostic accuracy based only on data from subjects with verified disease status are typically biased. This bias is known as verification bias. Here, we consider the problem of correcting for verification bias when continuous diagnostic tests for three-class disease status are considered. We assume that selection for disease verification does not depend on disease status, given test results and other observed covariates, i.e., we assume that the true disease status, when missing, is missing at random. Under this assumption, we discuss several solutions for ROC surface analysis based on imputation and re-weighting methods. In particular, verification bias-corrected estimators of the ROC surface and of VUS are proposed, namely, full imputation, mean score imputation, inverse probability weighting and semiparametric efficient estimators. Consistency and asymptotic normality of the proposed estimators are established, and their finite sample behavior is investigated by means of Monte Carlo simulation studies. Two illustrations using real datasets are also given.

Keywords : imputation, missing at random, inverse probability weighting, ROC surface analysis
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