STATISTICS

COLORADO STATE UNIVERSITY

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Linear regression using principal components from general Hilbert-space-valued covariates

Abstract

We consider linear regression with covariates that are random elements in a general Hilbert space. We first develop a principal component analysis for Hilbert-space-valued covariates based on finite-dimensional projections of the covariance operator, and establish asymptotic linearity and joint Gaussian limits for the leading eigenvalues and eigenfunctions under mild moment conditions. We then propose a principal component regression framework that combines Euclidean and Hilbert-space-valued covariates, obtain root-n consistent and asymptotically normal estimators of the regression parameters, and establish the validity of nonparametric and wild bootstrap procedures for inference. Simulation studies with two- and three-dimensional imaging predictors demonstrate accurate recovery of eigenstructures, regression coefficients, and bootstrap coverage. The methodology is further illustrated with neuroimaging data, in both a standard regression setting and a precision-medicine formulation.