Functional Principal Components Analysis, Regression and Covariance for Random Densities

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Samples of density functions appear in a variety of disciplines, including distributions of mortality across nations and distributions of voxel-to-voxel correlations of fMRI signals across subjects. The nonlinear nature of density space necessitates adaptations and new methodologies for the analysis of random densities. We define our geometry using the Wasserstein metric, an increasingly popular choice in theory and application. First, an adaptation of functional principal components analysis to densities is given by applying a preliminary transformation which maps densities to a Hilbert space; representations in this space are then mapped back to density space through the inverse map. Second, when densities appear as responses in a regression model, the utility of Frchet regression, a general purpose methodology for response objects in a metric space, is demonstrated. Lastly, a notion of Wasserstein covariance is proposed for multivariate density data, where multiple densities are observed for each subject, and its utility is shown via group comparisons.