High-order Imaging Regression via Internal Variation

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Abstract: The use of brain-imaging data to analyze cognitive disabilities has drawn increasing attentions in both psychology and public health. As brain-imaging data are usually represented by three or even higher order tensors, we aim to develop a class of high-order tensor (imaging) regression models to address this issue. A key novelty of our method is that it is able to account for the piecewise smooth nature of most imaging coefficients in the form of high-order tensors. This is achieved by an innovative approach named SHrinkage via Internal Variation (SHIV). The Internal Variation (IV) is designed to serve as a substitute of total variation (TV) for high order tensors. The SHIV is an IV penalized estimation and can be solved easily by a sequence of generalized Lasso problem. Theoretically, we simultaneously provide the computational and statistical errors of the SHIV estimates under a restricted eigenvalue condition and certain initialization requirements. Numerically, we conducted two simulation studies to demonstrate the accuracy of our method in brain region identification and tensor estimation. Furthermore, we analyzed the Philadelphia Neurodevelopmental Cohort dataset which includes pre-processing magnetic resonance images. Our analysis identified a subregion of cingulate cortex as being associated with verbal reasoning ability.