Longitudinal modeling of age-dependent latent traits with generalized additive latent and mixed models

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Abstract

Latent variable modeling is indispensable whenever a set of measured responses reflect some underlying latent traits of interest. In many applications, latent traits depend smoothly on variables like age and location, with functional shapes which are hard to specify a priori. However, most latent variable models require parametric forms for both latent and observed variables, and more flexible semiparametric models typically have limitations on the number of grouping levels or rely on restrictive assumptions like discrete time. We here present generalized additive latent and mixed models (GALAMM), which extend generalized linear latent and mixed models (GLLAMM) by allowing both observed and latent variables to depend smoothly on observed variables. GALAMMs retain the flexibility offered by GLLAMMs, including an arbitrary number of grouping levels and the ability to fit a large number of response types. By exploiting the mixed model view smoothing, we show that any model in the GALAMM framework can be represented as a GLLAMM and estimated by maximum likelihood. We propose a profile likelihood algorithm for model fitting, and derive expressions for asymptotic covariance matrices of both parametric and smooth terms. The applications motivating this work came from cognitive neuroscience, in which both latent cognitive abilities and structural characteristics of the brain follow smooth nonlinear trajectories across the lifespan, and we present three examples where GALAMMs enable answering research questions more easily than currently used tools. The properties of the models are further investigated in simulation experiments closely mimicking the real data analyses, and the results suggest that both estimates and standard errors are accurate with sample sizes commonly seen in applications.