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Linear Non-Gaussian Structural Equation Models

Linear structural equation models (linear SEMs) are widely applied in many empirical studies including social sciences, neuroinformatics and bioinformatics. Estimation of linear SEMs for continuous variables typically uses covariance structure of data alone and poses serious identifiability problems so that many important models including path analysis models are indistinguishable with no prior knowledge on the structures. A linear acyclic model which is a special case of path analysis models is typically used to analyze causal influences. Covariance information alone is not sufficient to uniquely estimate such a linear acyclic model and in most cases cannot identify the full structure (path coefficients and directions) of the model. Bentler (1983, PMK) proposed that non-Gaussian structures of data could be useful to overcome such identifiability problems of covariance-based estimation of SEMs. Recently we showed that use of non-Gaussianity allows the full structure of a linear acyclic model to be identified without pre-specifying any path directions between the variables (Shimizu et al., 2006, JMLR). The new method is based on a fairly recent statistical technique called independent component analysis (Hyvarinen et al., 2001, Wiley). We will first present an overview of linear non-Gaussian SEMs and then go to some recent advances we have made.

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Neural Test Theory: A Nonparametric Test Theory Using the Mechanism of a Self-Organizing Map

Neural test theory (NTT) is a nonparametric test theory that uses the mechanism of a self-organizing map. The latent scale assumed in the NTT is not continuous but rank-ordered, because a test does not have high enough reliability to continuously measure human abilities. That is, the most that a test can do is to sort examinees into several ranks. The NTT is a methodology for standardizing and equating tests provided that the latent scale is ordinal. The number of latent ranks is up to the teacher or test administrator, although it can also be statistically determined by using model-fit indices. The item reference profile (IRP) represents the expected correct answer ratios at respective latent ranks, and it is useful for reviewing the statistical characteristics of each item. The IRP does not always monotonically increases. However, a monotonic increase constraint can be imposed on the IRP in the estimation process. In addition, rank membership profile is the posterior distribution of each examinee's latent rank, and it can be used to determine the latent rank to which the examinee belongs. Furthermore, batch-type learning can be executed with an EM algorithm.

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Bias Reduction vs. Precision of Estimates in Mediation Analysis

Mediation analyses in the tradition of Baron and Kenny (1986) attempt to describe the extent to which the effect of an explanatory variable X on an outcome Y is carried through an intervening or mediating variable M. The analyst typically estimates the indirect (mediated) effect as the product of the structural coefficient (a) describing the effect of X on M and the structural coefficient (b) describing the effect of M on Y, adjusting for X. If measurement error in X and M is ignored, the product (a*b) is biased and is typically too close to zero. When such bias is eliminated using a measurement model in the context of SEM, the analyst might expect greater statistical power to test the indirect effect because of a larger effect size. However, the relative imprecision of the SEM estimate is usually larger than the bias reduction, leading to less power and precision for the unbiased analysis. We describe this pattern using simulation studies that vary the mediation effect size and the amount of measurement error in X, M and Y. We