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Bayesian Estimation of Multidimensional Latent Variables and Its Asymptotic Accuracy

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Abstract

Hierarchical learning models, such as mixture models and Bayesian networks, are widely employed for unsupervised learning tasks, such as clustering analysis. They consist of observable and latent variables, which represent the given data and their underlying generation process, respectively. It has been pointed out that conventional statistical analysis is not applicable to these models, because redundancy of the latent variable produces singularities in the parameter space. In recent years, a method based on algebraic geometry has allowed us to analyze the accuracy of predicting observable variables when using Bayesian estimation. However, how to analyze latent variables has not been sufficiently studied, even though one of the main issues in unsupervised learning is to determine how accurately the latent variable is estimated. A previous study proposed a method that can be used when the range of the latent variable is redundant compared with the model generating data. The present paper extends that method to the situation in which the latent variables have redundant dimensions. We formulate new error functions and derive their asymptotic forms. Calculation of the error functions is demonstrated in two-layered Bayesian networks.
Keywords: unsupervised learning, hierarchical parametric models, Bayesian statistics, algebraic geometry, singularities

1 Introduction

Hierarchical parametric models, such as Gaussian mixtures, Boltzmann machines, and Bayesian networks, are often used for unsupervised learning. These models use two variables to express their structure: observable variables that represent the