Comments on: Latent Markov models: a review of a general framework for the analysis of longitudinal data with covariates

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In recent years, longitudinal data have become increasingly relevant in many applications, heightening interest in selecting the best method to analyze multiple waves longitudinal datasets. General frameworks, that find justification in different types of analyses, can support the researcher in finding the most suitable model for the specific application. In this regard, Latent Markov (LM) models are of particular importance, especially in all those cases in which the interest is focused on the evolution of an unobservable characteristic of a group of individuals over time. LM models assume that the distribution of the observed variables is affected by a time-dependent latent process, that follows a Markov chain with a finite number of states. These models can be applied in different contexts, since the latent process can be interpreted as a “true” individual characteristic that is observable with errors due to several factors, or it can account for unobserved heterogeneity between the subjects, or even its latent states can be identified as different subpopulations.

The authors provide a detailed review of the current literature on latent Markov models given their extensive research in the analysis of categorical longitudinal data. The paper focuses on a general formulation of latent Markov models based on a first-order Markov chain, non-homogeneous transition probabilities, and covariates. It contains a comprehensive review of the historical genesis of these models clarifying the connections with methodological tools developed in other and affine research fields. The authors illustrate the assumptions of the basic version of the LM model, and introduce maximum likelihood estimation through the Expectation–Maximization algorithm. They cover constrained versions of the basic latent Markov model, describe

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the inclusion of the individual covariates, and also provide a discussion on Bayesian inference as an alternative to the maximum likelihood approach. A useful discussion concerning the interpretation of the model parameters, that is of the latent process, thereby making clear what are the most appropriate contexts of application is also included. To this aim, the paper describes a wide range of examples illustrating the use of these models.

This paper is particularly engaging and highly motivating containing a widespread discussion of important issues that are of extreme interest in the latent variable models. One of the most interesting features is that the authors provide generalizations of the basic LM model by relaxing classical assumptions, such as local independence of the response variables given the latent process. The basic idea is that the latter fully explains the observable behavior of a subject together with possibly available covariates. Although we can rely on this assumption in presence of univariate longitudinal data, it may be reasonable to assume that it does not always hold in presence of multivariate longitudinal data. In fact, in such case, the characterization of both temporal and cross-sectional dependencies among response variables is a challenging problem. In this context, it is natural to consider more complex models in which the dependency among responses within and across time can be explained using time-dependent latent variables and also item-specific random effects (see, e.g., [Dunson 2003](#); [Cagnone et al. 2009](#)).

In the basic LM model, the Markov chain accounts for the temporal dependence among the observed variables, whereas the latent class structure should explain the association among the responses at each time point. Conditional independence in latent class models is a widely discussed issue (see, e.g., [Reboussin et al. 2008](#), and references therein). It can be always achieved by increasing the number of classes, but this can yield spurious states that are not immediately interpretable even though the selected model may be optimal according to criteria based on goodness-of-fit statistics. This can heavily affect the computational burden of the LM model, since it is directly related to the number of latent states. To overcome this limitation, the authors rely on the results by [Bartolucci and Farcomeni \(2009\)](#), and allow for a form of contemporary dependence based on the specification of marginal log odd-ratios among the observed response variables. The approach is quite general and can be easily extended to account for serial dependence by including lagged values of the response variables as covariates. I found this to be an important point of the paper that ensures a greater flexibility to the basic LM model. The main limitation of this approach is that it is difficult to apply when the variables are of mixed type. In this regard, other solutions have been proposed in the latent class literature, and an alternative could be to incorporate specific random effects in the marginal logits as proposed by [Qu et al. \(1996\)](#). I would be interested to hear the authors answers on this and on other potential solutions.

Another issue that is widely debated in the latent variable literature is the most appropriate formulation of the latent process as either continuous or discrete. The LM model can be seen as a semi-parametric model, since the underlying Markov chain, characterized by a suitable number of states, may approximate any (even continuous) process with a first-order dependence structure. This allows to achieve a better fit to the data than continuous latent process formulations. But there is a reduced parsimony

since the number of parameters increases with the square of the number of states, making sometimes the interpretation of the model quite difficult.

A continuous alternative to the LM model has been recently proposed by [Bartolucci et al. \(2014\)](#). It consists of a model in which the time-dependent latent process is assumed to be characterized by a mixture of latent autoregressive processes of order one, denoted by MLAR (k). k indicates the number of components, each having a specific mean and correlation coefficient, but having all the same variance to avoid unstable estimation results. This model shares some advantages with both the classical continuous Latent AutoRegressive (LAR) model and the LM model, but, at the same time, overcomes some of their main limitations. In particular, as the former, the MLAR is very parsimonious being the latent structure represented by few parameters, but achieves a fit comparable to that of the LM model. However, with respect to the latter, it seems to be less affected by the problem of multimodal likelihood. Hence, I think that the availability of both MLAR and LM models could help the researcher to choose the best alternative formulation for the latent process tailored to the specific application.

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