10 Penalising model component complexity: A principled practical approach to constructing priors

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Setting prior distributions on model parameters is the act of characterising the nature of our uncertainty and has proven a critical issue in applied Bayesian statistics. Although the prior distribution should ideally encode the users' uncertainty about the parameters, this level of knowledge transfer seems to be unattainable in practice and applied statisticians are forced to search for a "default" prior. Despite the development of objective priors, which are only available explicitly for a small number of highly restricted model classes, the applied statistician has few practical guidelines to follow when choosing the priors. An easy way out of this dilemma is to re-use prior choices of others, with an appropriate reference.

In this talk, I will introduce a new concept for constructing prior distributions. We exploit the natural nested structure inherent to many model components, which defines the model component to be a flexible extension of a base model. Proper priors are defined to penalise the complexity induced by deviating from the simpler base model and are formulated after the input of a user-defined *scaling* parameter for that model component, both in the univariate and the multivariate case. These priors are invariant to reparameterisations, have a natural connection to Jeffreys' priors, are designed to support Occam's razor and seem to have excellent robustness properties, all which are highly desirable and allow us to use this approach to define default prior distributions. Through examples and theoretical results, we demonstrate the appropriateness of this approach and how it can be applied in various situations, like random effect models, spline smoothing, disease mapping, Cox proportional hazard models with time-varying frailty, spatial Gaussian fields and multivariate probit models. Further, we show how to control the overall variance arising from many model components in hierarchical models.

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