Biadditive Mixed Models - Advancing Computational Methods and Applications

Analysis of Variance (ANOVA) is widely used to analyze data in most scientific areas. However, the standard linear ANOVA models are not always adequate to describe the structures in a data set sufficiently. This means that an improved inference and a better insight might be obtained by extending the linear ANOVA models. An example of this, is the multiplicative models also named biadditive models, which arise when one or more multiplicative terms are added to a linear ANOVA model. These models are especially popular within agriculture to analyze genotype-by-environment data, but they are also used in e.g. sensometrics to analyse sensory profile data or in medicine to analyze data from method comparison studies. In general, these models are relevant whenever an interaction between two factors is not completely unstructured, but can be described either fully or partly by a linear regression, where one of the variables in the multiplicative term can be interpreted as the regressor and the other variable as the slope.

In this thesis, the main focus is on a specific version of the multiplicative mixed models, with the multiplicative term being a product of a fixed effect and a random effect, where the fixed effect is a part of the mean structure. This means that this fixed effect enters both the mean and the variance structure, which complicates the estimation of the model. One main goal of this work was to develop a user-friendly open-source software tool to fit this kind of models. For this purpose, R-package mumm was created, which is now available on CRAN. The thesis demonstrates how to use the package, which was found to be faster than the commercial alternative. Another aim of this thesis was to investigate the advantages obtained by using the multiplicative mixed model, instead of a simple linear mixed ANOVA model. By simulation studies, it was demonstrated that the power to detect a significant fixed effect increases by using a multiplicative mixed model instead of a two-way mixed ANOVA model, when the 'multiplicative effect' is present in the data.

In sensometrics, a linear approximation to the multiplicative mixed model was presented in Brockhoff et al. (2015). This model is named the Mixed Assessor Model (MAM), and is used to analyze sensory profile data, where a panel of judges assess different products and scores them in relation to a specific characteristic. In this thesis it was showed that also by using the MAM instead of a standard two-way mixed ANOVA model, an increased power to detect significant product differences can be obtained. The power gain by using the MAM was, however, found to be smaller than when using the multiplicative mixed model. Therefore we have proposed a new F-test, which increases the power of the MAM. In Brockho et al. (2015), a method to produce confidence intervals for product differences, based on the MAM, was suggested. This method has been evaluated, and we demonstrated that it works well, resulting in confidence intervals that behave similar to the profile likelihood based confidence intervals estimated by the mumm package.

Further, the thesis gives an overview of the different biadditive (mixed) model versions, including a literature review and a description of their applications. Finally, it was demonstrated how these models can be estimated by the Rpackage TMB (Template Model Builder).