PROC GLIMMIX and Linear Mixed Models

To fit a linear model with or without random effects, you can use PROC GLIMMIX. Before SAS introduced PROC GLIMMIX, PROC MIXED was used to fit linear mixed models. PROC GLIMMIX offers capabilities that are not available in PROC MIXED, so you learn about PROC GLIMMIX in this lesson. By the way, PROC GLIMMIX can also be used to analyze repeated measures data because of its large selection of variance-covariance matrices.

The PROC GLIMMIX syntax for fitting a linear mixed model includes the following statements: CLASS, COVTEST, LSMESTIMATE, MODEL, and two RANDOM statements – one with and one without the _RESIDUAL_ keyword. The RANDOM statement without the _RESIDUAL_ keyword is the only statement that was not shown in previous lessons. Let's take a quick tour of these statements.

The CLASS statement specifies the classification variables to be used in the analysis. The COVTEST statement provides a mechanism to obtain statistical inferences for the covariance parameters. Significance tests are based on the ratio of residual likelihoods or pseudo-likelihoods. Confidence limits and bounds are computed as Wald or likelihood ratio limits. The LSMESTIMATE statement requests custom hypothesis tests among the least squares means. In an earlier lesson, the LSMESTIMATE statement was used in PROC PLM. The MODEL statement specifies a single response variable and the fixed effects. You do not specify random effects in the MODEL statement. Instead, the first RANDOM statement specifies the random effects. The random effects can be categorical or continuous effects. You'll learn how to specify random effects in more detail later in this lesson.

Specifically, the first RANDOM statement defines the Z matrix of the mixed model, the random effects in the γ vector, and the structure of G (the covariance matrix for the random effects). The second RANDOM statement (the one with the _RESIDUAL_ keyword) specifies the structure of R (the covariance matrix for the random errors). In other words, this RANDOM statement specifies the variance-covariance structure of the errors that is not the default $\sigma^2 I_n$. Be careful when you specify more than one RANDOM statement in PROC GLIMMIX. In some cases, one statement with the specified variance-covariance structure captures all the variations in your data and is sufficient.

PROC GLIMMIX distinguishes two types of random effects. If the variance of the random effect is contained in the G matrix, then it is called a G-side random effect. If the variance of the random effect is not an element of G, it is contained in the R matrix and is called an R-side random effect. R-side effects are also called residual effects. Models without G-side effects are known as marginal (or population-averaged) models. All random effects are specified by the RANDOM statement in PROC GLIMMIX. Note that estimation is more difficult in the linear mixed model than in the general linear model. In addition to estimating the fixed effects that appear in both models, the linear mixed model also requires estimation of the random effects, the covariance structure of the random effects, and the covariance structure of the random errors.

For linear mixed models, PROC GLIMMIX uses the following estimation methods: To estimate variance and covariance parameters for normally distributed data, PROC GLIMMIX uses the restricted maximum likelihood method or the maximum likelihood method. To estimate fixed-effect parameters and standard errors for linear mixed models, PROC GLIMMIX uses the generalized least squares (or GLS) estimation method. The GLS method requires knowledge of the G and R variance-covariance matrices and therefore is more appropriate for linear mixed models than the ordinary least squares method. Ordinary least squares is no longer the best method because the distributional assumptions regarding the random error terms are too restrictive. In other words, the parameter estimates are no longer the best linear unbiased estimates.

For additional details about the comparison of the generalized least squares and ordinary least squares methods for linear mixed models, click the Information button. To learn more about using PROC GLIMMIX for a variety of statistical analyses, you can take additional SAS training. A list of related SAS courses is available in the Help and Resources section of this course.