Numerous computer programs have been written to analyze data under the fixed linear model. Many of these are available for a nominal charge. Most of these programs seem to have been written as ordinary multiple regression programs but some of them do contain options which allow the user to obtain sums of squares for discrete sets of effects and adjusted or least squares treatment means.

The Least Squares and Maximum Likelihood General Purpose program (LSMLGP) which is contained in the User-Contributed Procedure Library of the Statistical Analysis System (SAS) was written to handle both discrete and continuous independent variables directly. Estimates of crossclassified and/or nested effects, interaction effects and partial regression coefficients for continuous independent variables are obtained from a solution of the least squares normal equations. Least squares or adjusted class and subclass means are then automatically computed by using appropriate linear functions of the estimates of the effects. Standard errors of these adjusted means are also computed and listed. Linear contrasts of treatment or interaction effects with tests of significance may then be obtained if desired by the user. Sums of squares for each degree of orthogonal polynomials through the fifth degree involving treatment effects may be obtained even though one has unequal intervals among levels and even though adjustment is being made for unequal subclass frequencies or for covariates.

UNIQUE FEATURES IN LSMLGP

Absorption of Equations: One set of equations may be absorbed into the equations for other effects remaining in the model under this option. This option is especially useful when one has one set of effects, either crossclassified or nested, which contains a large number of effects. The effects for classes or subclasses absorbed may be for either fixed or random effects. The estimates obtained for other effects in the model after absorption are adjusted for the effects that were absorbed, i.e., these are the same estimates that would have been obtained if all LS equations were solved simultaneously. The adjusted sum of squares for the absorbed effects may be obtained by rerunning the analysis ignoring these effects.

Estimation of Variance Components: Variance and covariance component estimates may be obtained with LSMLGP for several non-interacting crossclassified or nested sets of effects provided the constants for such effects are fitted directly along with constants for fixed effects. When estimating variance and covariance components an investigator usually has a fairly large number of classes for the random set of effects. Therefore, this option is largely limited to those problems where the model would contain only one or at most two non-interacting crossclassified or nested sets of effects where the total number of degrees of freedom for such effects is less than one hundred.
Estimation of Heritability and Genetic Correlations. If the variance and covariance component estimates obtained under the IRAN option contain genetic components one can make use of a feature in LSMLGP to obtain estimates of heritability and genetic correlations along with approximate standard errors. Also, phenotypic and environmental correlations are computed and listed under this option.

Maximum Likelihood Analyses. With these analyses differences among treatments that exist among random crossclassified or nested effects are combined with ordinary least-squares estimates of treatment effects to "best" estimate treatment differences. To do this one must have an estimate of the intraclass correlation among observations in the same random class. Variance components needed to estimate this intraclass correlation from the data may be obtained with LSMLGP when the number of random classes is not too large as explained above. In many cases the investigator will have a reliable estimate of this intraclass correlation from outside the data. In addition to the use of these maximum likelihood options for the recovery of interblock treatment effects, these options are extremely useful in animal breeding data to separate genetic and environmental trends.

Orthogonal Polynomials fitted to Estimates of Treatment Effects. After estimates of treatment effects are obtained from the solution of the LS equations use is made of the variance-covariance matrix for such effects to sequentially complete weighted least squares analyses which give the sums of squares for single degree of orthogonal polynomials. Using this procedure one can have unequal intervals between levels and, of course, adjustments for unequal subclass frequencies or covariates. The non-orthogonal partial regressions for each degree of polynomial are listed for each dependent variable for plotting the selected curve. Tests of significance are given in the analysis of variance table for each degree of polynomial. This option is available to the user for any crossclassified or nested set of effects.

Non-orthogonal Polynomials for Continuous Independent Variables. LSMLGP will automatically compute partial regression coefficients for linear, linear and quadratic or linear, quadratic and cubic non-orthogonal polynomials. The user selects the set of polynomials desired for each continuous independent variable simply by placing a 1, 2 or 3 in a given column of the parameter card.

Linear Contrasts Among Treatments. By providing appropriate parameter cards to LSMLGP the user may obtain any linear function desired among any of the constants fitted along with the standard error of the linear function. If the linear function is a contrast among treatment effects the user may then compute a "t" test to obtain a significance test, if desired.

Correlations Among Independent Continuous Variables and Among Dependent Variables. All correlations possible among all dependent variables may be obtained with LSMLGP on a total or within class or subclass basis (depending on whether equations are absorbed or not) and on an "error" or "residual" line basis. The correlations involving independent continuous variables, either with themselves or with the dependent variables, are computed on the basis on which the LS equations are being set up, i.e., on a total or within class or subclass basis. A user may use LSMLGP merely to compute a set of product-moment correlation coefficients among a set of continuous variables if desired without completing any LS analysis.
Class and Subclass Frequencies. Identification of each class and subclass as specified by the sets of constants being fitted along with the number of observations found in each class or subclass are listed. These frequencies are also given in the table which gives the LS means and standard errors for ready reference. If two-way subclasses are found to be missing and these have not been indicated as being missing on the parameter card the analysis is discontinued. However, the program does allow for the fitting of interaction constants even when some subclasses are missing.

Variable Options for Listing. Provisions are made in LSMLGP to list the reduced X matrix, the Y matrix, equations for classes or subclasses being absorbed, the X'X and X'Y matrices as well as the class and subclass frequencies, the inverse elements and the results from the analysis, if desired. One has the option of listing each element in X'X, X'Y and (X'X)^{-1} on a separate line with complete identification if desired or the listing of X'X and X'Y can be omitted and the elements of (X'X)^{-1} are then listed without identification with seven elements per line in floating point notation.

LSMLMM

A more complete mixed model program which makes extensive use of indirect procedures for computing sums of squares and crossproducts for random effects and the coefficients for such components in mean squares and mean crossproducts was released in September 1972. This program, referred to as LSMLMM, is not available in SAS. However, it is available from the author for a nominal service charge of $75.00. About 80 installations throughout the world are making use of this program. It is especially useful when one has a very large number of degrees of freedom for random sets of effects and/or there are interactions among random and fixed sets of effects.

I should also mention in closing that I have been adding some additional features to LSMLMM and hope to have a new release of this program by next summer. The new version will allow users to compute individual regressions for continuous independent variables separately for each treatment group, if desired, and will provide for general weighted least-squares analyses.