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Distribution Theory for Henderson's Estimates in "Partially Balanced" Mixed Models

Mark G. Vangel
National Institute of Standards and Technology

This presentation examines a simple and least intuitive way to estimate variance components in mixed models – perform as many ordinary -square regressions as there are variance components, using dummy variables for all but one random effect in each regression. By equating these residual sums of squares to their expectations, unbiased estimates of all of the variance components can be obtained. This approach is essentially Method 3 of Henderson (*Biometrics* 1953). A special class of mixed models (called *partially balanced)* is introduced, in which all of the random effects are balanced and nested, and each is nested within the fixed effects, *except for the "outermost"* which is arbitrary, so one as the constraints on the other random effects are satisfied. For partially balanced models, the distributions of Henderson's variance component estimates will be derived. Applications to the analysis of composite material strength data will be discussed.

Perpendicular Least Squares Fit to a Sample of Data

Arthur E. Hoerl (Emeritus Professor)
University of Delaware

One of the students (Barry Rodin from Aberdeen Proving Ground) in an advanced course in regression brought in a sample of data generated by a model defined by

$$(x - a)(y - b) = c.$$

Because of the obvious problem associated with nonconstant variance, standard least squares could not be applied. As an alternative, it was decided to minimize the sum of perpendicular squared errors. This turned out to be a very complicated and tedious procedure. However, the problem was solved by using a variety of computational tricks. The results proved to be extremely interesting, with broad generalities.

A Penetration Equation for Aluminum-Kevlar Composites

Barry A. Bodt
Ricky L. Grote
U.S. Army Research Laboratory

Vulnerability analysts are often given the assignment to predict what will happen when a proposed threat meets a proposed target. They rely on information from existing threats, targets, and models to support these analyses. In preparation for evaluating the vulnerability of the command and control vehicle (C2V), analysts recognized the need for an improved model to predict the residual mass and velocity of a penetrator once is has passed through an armor. Existing models were not completely suitable for this application because the proposed armor was not a single homogeneous material, but rather was an aluminum-kevlar composite. In this presentation, we will highlight the role of penetration models in vulnerability analyses, and we will discuss the experimental program and modeling effort leading to the development of a penetration algorithm suitable for predicting residual mass and velocity of armor-piercing (AP) projectiles against aluminum-kevlar composites.

Desert Field Evaluations of Bradley Fighting Vehicle Camouflage Systems

George Anitole
Ronald L. Johnson
Night Vision Electronic Sensors Directorate

Christopher J. Neubert
U.S. Army Materiel Command

The Bradley Fighting Vehicle requires a camouflage system which does not adversely impact the operational requirement of high mobility. An in-house camouflage system, consisting of form-fitting camouflage turret covers and four types of camouflage skirt nets, was constructed. A field evaluation to determine system blend with desert terrain was conducted in Arizona. Ten camouflage combinations were paired with each other and viewed at different ranges starting at 500 m. Ground observers had 3 minutes to view each pair of target conditions to determine best blend with the desert terrain. Time constraints prevented fabrication of duplicate sets of skirt nets and turret covers. Thus, paired comparisons involving multiple turret covers or similar skirt nets were not possible. An analysis of variance revealed significant ($\alpha \leq 0.05$) differences in desert terrain blending among the camouflage conditions. The Scheffé procedure multiple range and Kruskal-Wallis multiple range analysis indicated that the use of camouflage skirts was more significant ($\alpha \leq 0.05$) in blending the Bradley to the desert terrain than the use of turret camouflage.

Force Enhancement with Precision-Guided Mortar Munitions

Paul J. Deason
Stanley M. Gray
U.S. Army TRADOC Analysis Center–WSMR

This paper will present the result of analysis investigating the contribution of the mortar to the combined arms battle and the synergism with other weapon systems. In particular, this study investigated the potential of replacing a part of the direct fire early entry force with mortars firing "smart" precision-guided munitions for counter maneuver attrition. What is interesting is the force synergisms seen in the combat simulation results showing the value to the force of the mortar – because the mortar is busy firing smart munitions, its contribution to force protection by providing smoke cover is reduced.

This study was performed by the U.S. Army TRADOC Analysis Center–WSMR for the Program Manager–Mortar using the CASTFOREM high-resolution force-on-force combat simulation model and early entry scenarios in South-West Asia and Latin America.

Javelin - Performance Evaluation

Samuel Frost
Paul Ferguson
U.S. Army Materiel Systems Analysis Activity

The Javelin weapon system (previously known as the Advanced Antiarmor Weapon System–Medium [AAWS-M]) is a man-portable, shoulder-launched fire and forget imaging infrared missile system. Since this missile is one of the first (if not the first) smart weapons for infantry, it has presented the Army community many challenges in evaluating it properly. The U.S. Army Materiel Systems Analysis Activity (AMSAA) utilized a computer simulation (the Integrated Flight Simulation [IFS]) and designed a factorial test to determine both probability of hitting the target and actual impact point on target. The dependent variables were the impact points in the plane normal to the target at closest approach (although for a time it degraded into simple hit or miss), and the independent variables were range, target motion, target signature, target aspect angle, background clutter, and temperature difference between target and background (to accomplish this, AMSAA suggested new methods of measuring and quantifying the factors).

The results of this experiment have yielded a better understanding of how the Javelin functions, in addition to giving estimates for the system lethality which were critical for the Javelin system passing into low-rate initial production (MSIIIA). In calculating these lethality estimates, AMSAA made no up-front assumptions instead of relying on EDA techniques to characterize the distribution of impact points which were then coupled with U.S. Army Research Laboratory, Survivability/Lethality Analysis Directorate vulnerability files to obtain the final probability of kill estimates.

Plans are now being made to utilize a similar design to assess the Javelin's performance in the presence of countermeasures.

Resolution of Production Problems Through Controlled Experimentation

Kristen Vogelsang
U.S. Army Armament Research, Development, and Engineering Center

In the past decade or more, it has become increasingly apparent that it is essential to maintain a close working relationship with production facilities and contractors to ensure quality performance. The U.S. Army Armament Research, Development, and Engineering Center at Picatinny Arsenal, NJ, has had a long history of working with the Lake City Army Ammunition Plant (LCAAP), – a Government-owned contractor-operated facility – the main producer of small-caliber ammunition for the U.S. military.

In 1993, LCAAP experienced difficulties in the production and testing of both Tetracene – an initiating explosive used in ammunition primers – and the 7.62-mm M276 Dim Trace Cartridge. To resolve the problems, Government and contractor personnel worked together in a controlled investigation of the manufacturing process and acceptance testing of both these items. As part of this investigation, test matrices were developed employing use of the Taguchi Method of Quality Engineering. The intent of the matrices was to determine the controlling variables within the process and test methods.

These efforts resulted in a better understanding of the factors affecting the production, performance, and test methodology of Tetracene, ultimately allowing the plant to avoid any production delays. The M276 Dim trace performance was refined and improved through changes to the manufacturing process that were verified through use of the test matrices. The M276 production was restored and has since avoided further delays. Controlled experimentation has proven worthwhile in both instances and because of the cooperative efforts between Government and contractor, a timely solution was achievable.

Multivariate Goodness of Fit Testing Using Statistically Equivalent Blocks and Proximity-Based Cutting Functions

Keith E. Matthews
U.S. Military Academy

Malcolm S. Taylor
U.S. Army Research Laboratory

We demonstrate a method of performing a Goodness of Fit Test (GoFT) on two samples of multivariate data. Given a sample of observations of a multivariate random variable X, and a second sample of observations of a multivariate random variable Y, our goal is to develop a methodology for testing whether X and Y are identically distributed. The method we demonstrate does not require that we estimate the underlying distribution of X or Y. Rather, we first use the method of Statistically Equivalent Blocks (SEB) to reduce the samples to one dimension. We then use a Smimov two-sample test on the resulting one-dimensional samples. This method promises to be powerful against a broad range of alternatives and will be of use in such areas as verifying the result of computer models of measurable phenomena, when such models produce multivariate output.

A Multivariate Rank Sum Test for Network Simulation Validation

Ann E. M. Brodeen
Malcolm S. Taylor
U.S. Army Research Laboratory

Simulation is a widely accepted means of analyzing systems that are too complex to model analytically. Most communications systems fall into this category. But simulation credibility suffers when a continuing verification and validation program is not undertaken, thereby diluting the value of analyses that simulations support. Multivariate methods can be used to test the hypothesis of agreement between simulated predictions and empirical observations. This paper describes a statistical test useful for the validation of simulations of (battlefield) communications networks. The method employs a multivariate nonparametric rank sum test with the aid of a computer-intensive permutation procedure to assess the significance of the defined test statistic. For illustrative purposes, the validation procedure is applied to a simulation that was developed to duplicate a configuration tested in FY91 in which "messages" were passed over a communications network using the combination of the Tactical Fire Direction System (TACFIRE) protocol and Single-Channel Ground and Airborne Radio System (SINCGARS) Combat Net Radios (CNR).

Modeling the Auditory Detection of the Squad Automatic Weapon Magazine

Georges Garinther
Joel Kalb
Jock O. Grynovicki
U.S. Army Research Laboratory

The Human Research and Engineering Directorate (HRED) conducted an evaluation of the auditory detectability of eight prototype configurations of the Squad Automatic Magazine Weapon (SAW) during running, walking, and jumping activities. The evaluation utilized a repeated measures design and was conducted on a grass-covered, relatively quiet, open field at Spesutie Island, Aberdeen Proving Ground, MD. It consisted of measuring the noise produced by each magazine for each activity and using a panel of 12 listeners to determine the distance at which they were able to hear the noise. Listeners were located at 40, 65, 100, and 150 m from the magazine-carrying soldiers. The noise measurements were used to compute detection distance using the HRED Auditory Detection Model (ADM).

ADM has the capability of computing:

1. The distance at which a target can be detected by unaided human hearing,
2. The propagation losses and noise spectrum at any distance from a measured noise source, and
3. The one-third octave-band spectrum not be exceeded for nondetection at any specified distance.

Results revealed that the auditory detection distance of the different magazines varied based on their configuration and material composition. Full magazines made from softer material demonstrated shorter detection distances than the standard hard magazines. Finally, the aural detection probabilities of the different magazines based on the panel of listeners and ADM model computed predictions were compared. The ADM results agreed with the listeners for continuous stimulus such as running and walking.

A Statistical Fail-Safe Methodology for Fatigue-Loaded Components

Donald M. Neal
SRRC

William T. Matthews
NASA

This paper introduces a fail-safe design concept using a Monte Carlo simulation process applied to fatigue life model used in an American Helicopter Society (AHS) round-robin study. The concept is represented by a redundant (dual load path) unequally stressed two-element system. The simulation process determines a random set of system lifetime values and their corresponding reliability values. The process involved randomly selecting spectrum stress cycle and materiel fatigue strength values from known probability density functions (PDFs) defined by the mean stress and strength values from the AHS study.

The redundant system capability was compared with a fail-safe two-element standby system. Results showed the redundant system lifetimes, for both the first and second element time to failure, were much greater for the same reliability and equal system weight. A relatively small weight penalty was observed from application of the redundant system when compared to the standby system.

Comparing Weibull versus normal PDF applications showed increasing differences in lifetime estimates for increasing higher reliability values. Only for a lower reliability of one nine did the results show good agreement between the normal and Weibull application. From this result, reliability-based structural performance of various candidate designs for R = 0.9 could be compared analytically in order to assess the relative merit of the designs.

Power Study for a One-Sided Hypothesis Test of Two Independent Variance Components

David W. Webb
U.S. Army Research Laboratory

Between-occasion variation is an important variance component in the overall dispersion of tank weapon systems. To determine if engineering changes to the tank are able to lower the between-occasion variation, a designed experiment was requested. One proposal called for two nested designs, yielding independent estimates of $\sigma^2_{OCC\text{-}TRT}$ and $\sigma^2_{OCC\text{-}CTRL}$. The ensuing analysis would use generalized p-values to test the null hypothesis $H_o : \sigma^2_{OCC\text{-}TRT} \geq \sigma^2_{OCC\text{-}CTRL}$. In order to determine the power of this test procedure, a rigorous computer simulation of the experiment and ensuing analysis was performed. Results indicated that, as proposed with the current sample size restrictions, this design offers slim chances for rejecting H_o even if the optimistic assumption $\sigma^2_{OCC\text{-}TRT} / \sigma^2_{OCC\text{-}CTRL} = 0.50$ is made.

Statistical Analysis of Turbine Engine Diagnostic (TED) Field Test Data

John T. Monyak
University of Delaware

Malcolm S. Taylor
U.S. Army Research Laboratory

During the summer of 1993, a field test of turbine engine diagnostic (TED) software, developed jointly by the U.S. Army Research Laboratory and the U.S. Army Ordnance Center and School, was conducted at Fort Stewart, GA. The data were collected in conformance with a cross-over design, some of whose considerations are detailed. The initial analysis of the field test data was exploratory, followed by a more formal investigation. Technical aspects of the data analysis and insights that were elicited are reported.

Use of Logistic Regression Analysis to Evaluate Tick Repellent Data

J. Robert Burge
Douglas B. Tang
Walter Reed Army Institute of Research

A field evaluation of two repellent formulations against ticks is analyzed by approaching the problem via logistic regression rather than by means of analysis of variance. Logistic regression, a statistical technique for modeling the relationship between a dichotomous outcome variable and a set of covariates, has been in use for many years. Nevertheless, presentation and interpretation of results typically treated by ANOVA will be illustrated within the framework of the binary logistic regression model.

Curve Fitting of Nonlinear Ride Curves and Measuring the Effect of Varying Tire Pressure on Vehicle Ride Performance

Andrew W. Harrell
U.S. Army Engineering Waterways Experiment Station

This paper discusses the application of a nonlinear regression technique for describing the relationship between vehicle ride performance and surface roughness. The ride performance vs. surface roughness data were obtained from simulations using a vehicle dynamics model to describe the performance of a 10-ton heavy-expanded mobility tactical truck. Input parameters for the model were derived from instrumented vehicle drop tests from which spring and damper coefficients are estimated. Tire deflections were also measured. The resulting program runs are then used to evaluate the effects of tire pressure on ride performance. The sensitivity of the regression curves to variations in tire pressure are presented in the form of graphs. Curves considered for the best fit come from a two-parameter linear envelope of hyperbolas whose asymptotes are the vertical and horizontal axes. The nonlinear curve-fitting method used utilizes the singular value decomposition of design matrix of the fitting problem. This matrix evaluates the two members of the envelope of functions at the data points. Future work will result in recommendations for an appropriate design of experiments to collect experimental data to verify and validate the program's simulations.

Experimental Design Considerations in the Battle Lab

Eugene Dutoit
Dismounted Battlespace Battle Lab

The mission of the Dismounted Battlespace Battle Lab is to define the needs and integrate the battlespace requirements of the combined arms team from individual to brigade. The Dismounted Battle Lab will develop, experiment, and evaluate all close combat activities to support force modernization decisions that will maintain the technological edge our soldiers must have to dominate future battlefields. The Dismounted Battle Lab must integrate and coordinate with other Battle Labs and proponents to improve the force in terms of doctrine, training, leader development, organization, and soldier domains. This paper will present some examples of how experimental design considerations were applied to some Battle Lab activities during the past year in order to accomplish the above stated mission. The examples will come from some of the Advanced Warfighting Experiments (AWEs) that were conducted for evaluations. Other examples will come from the Battle Labs involvement with force-on-force simulations and the annual Infantry Commanders Conference held at Fort Benning, GA. Lessons were learned and some of these will be shared. Finally, the paper will share some ideas for future applications of experimental design as they could relate to the Army’s model-test-model philosophy and the evaluation and integration of new models and simulations in support of the Land Warrior Test Bed.

Analysis of Simulation Data for the TARDEC Virtual Prototyping Process

Albert Van Horn
U.S. Army Tank-Automotive Command

The intention of the Virtual Prototyping Process is to produce advanced concepts through the use of computer-aided design and research. The advanced concept is then evaluated using performance modeling. Dynamic simulations are then used to evaluate the concept. Critical factors, such as mobility, survivability, vulnerability, and lethality are analyzed.

This analysis compares alternative concepts by using War Game simulations. The model is configured to represent each alternative. Next, the model is run several times with each configuration. Output from several runs of each alternative is compared.

As a matter of fact, the most common mode of operation is to make a single simulation run of somewhat arbitrary length and then treat the resulting estimates as being the “true” answers for the model.

Several methods of statistical analysis are currently being used to evaluate the data from our War Game models. We would like the opportunity of having your panel of experts review our methods and make recommendations.

Analysis of Subjective Data

Fred M. Grimes
TEXCOM

In operational tests, the tester tries to get as much data as possible by using instrumentation. Instrumented data reflects the actual events with little bias introduced by individuals. However, there are times when subjective data is the only method of obtaining information on a tested item. In a recent test, the test participants were asked to compare the command and control capability of one model of a tank with another. A questionnaire was given to the participants at several points in the test and they were asked to mark one of seven responses – strong agree, agree, slight agree, slight disagree, disagree, strong disagree, and not applicable. Several questions, such as, (a) I knew the location of friendly units within my area of operation, (b) I knew the mission of friendly units within my area of operation, etc., applied to a given subject such as “knowledge of friendly dispositions.” The responses to the questions were tallied and summarized by subject.

An analysis of the data consisted of determining the arithmetic means of each question and subject. A chi-squared test using the SAS programs was made on the summarized subject data to determine if there was a significant difference in the two summarized responses. If the comparison revealed a significant difference, then a review was made of the means of the question and subject responses. The tank with the lowest means was considered the best for that subject. The subject responses were then tallied to determine which tank was dominant (better).

Interpretation of Interaction Effects in Fixed and Random Models

Jock O. Grynovicki
U.S. Army Research Laboratory

This paper presents three approaches used to investigate and interpret interaction effects in fixed or random models. The first approach is the traditional method of interpreting interactions for fixed effects and involves examination of the differences between original treatment cell means. An alternative approach proposed by Rosnow and Rosenthal in the *Psychological Bulletin* (1989) involves the decomposition of cell means into main and interaction effects. The interaction effects are then defined in terms of the cell means corrected for the main effect which provides residual information. These two approaches were applied to data from a factorial experiment and compared.

The third approach is new. It evaluates random interaction by using probability distribution theory for variance component diagnostics proposed by Grynovicki and Green (1990). The goal of the researcher is to estimate the contribution of random effects to the variance of the dependent variable and to interpret the source of significant interactions. The diagnostics are averages of sample covariances, which may be independent or correlated. The distribution theory provides a formal basis for identifying and explaining significant interactions. This technique is illustrated using data from an Army experiment designed to evaluate various helicopter flight controls during flight simulations.

A Study of Line-of-Bearing Errors

Andrew A. Thompson
Gary L. Durfee
U.S. Army Research Laboratory

Many systems use line-of-bearing (LOB) information to locate distance objects. The errors in location due to noisy LOB measurements are the focus of this paper. A central assumption for these systems is that the LOB-location errors are adequately modeled by bivariate Gaussian distributions. These systems typically use weighted averages to estimate a target's location. Weighted averages for bivariate data are discussed in Alexander (1980) and Thompson (199la). Recursive estimators update the estimate by a gradient based on the current observation. The Kalman filter is a recursive estimator that uses the covariance of an observation to determine the influence of that observation on the current estimate.

A discussion in Thompson and Durfee (1992) illustrates that these location errors are not necessarily Gaussian. In some situations, reasonable errors lead to calculations of implausible target locations. In addition, it was demonstrated that the location distribution is skewed in the direction of increasing range – thus, bias is a problem.

This paper investigates the properties of the errors associated with LOB locations. Guidelines are suggested for various assumptions about LOB-location errors. The concept of the stability ratio is introduced and used to determine the possibility of encountering implausible LOB locations, as a means of predicting the existence and magnitude of estimator bias; to determine the applicability of using a bivariate normal distribution for modeling LOB errors; and for determining the utility of closed form models to predict the covariance of LOB locations.

Analysis of the Armored Vehicle Survivability Enhancement Study

Paul J. Deason
U.S. Army TRADOC Analysis Center–WSMR

Wanda L. Phillips
Booz-Allen and Hamilton, Inc.

As a follow up to a paper presented in the technical session at the 39th Department of Energy conference, this paper will present the results of the analysis of several proposed means of enhancing the survival of a direct fire armored vehicle, the Line-of-Sight Antitank (LOSAT) weapon system. Various means of signature reduction and countermeasures against direct (ground and airborne) and indirect fire systems were applied to the LOSAT. The effectiveness of these systems were then evaluated using European and SWA scenarios in the CASTFOREM high-resolution combat simulation model. The result of these survival studies has direct application to the use of a long-range direct fire system such as the LOSAT or other armored systems are used as a "hunter" system, when trying to establish a position or expand a lodgment, and when faced by advanced conventional threat. By reducing the signature of the vehicle, the chance of being detected and targeted is reduced. If detected and targeted, the use of countermeasures enhances the probability of survival.