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On parametric and nonparametric analysis of two factor factorial experiment

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Abstract
Data for one or more of factors levels in factorial experiment analyzed by a usual factorial ANOVA from a population whose distribution violates the assumptions of normality, the results on the original data may provide misleading results or it may not be the most powerful tests. In such cases transforming the data using proper data transformation technique or using non parametric tests may provide better estimation. In this paper, we analyzed two factor factorial experiments which violate assumptions of normality using usual parametric factorial ANOVA, various data transformation techniques applying to original data and non-parametric method (Aligned rank method). The results show significant differences for different tests. So, here we proposed analytical procedure of aligned rank transformation when data violates several assumptions of parametric ANOVA to avoid consequences in the datasets.

Keywords: Two factor factorial experiment, parametric factorial ANOVA, data transformation techniques, aligned rank transform method

1. Introduction

Studies from agricultural field experiments generally violate assumptions of normality of data and this assumption is important assumption to analyze any field experiment. In factorial experiment we have test effects of different factors at their different levels which results in testing Main factor effects as well as interaction effects of factor levels but sometimes data from factorial experiments violates assumption of factorial ANOVA. In that case analysis of variance using usual parametric ANOVA tests may mislead our results and we may misinterpret our data which will affect our future decision planning. So, choice of proper analysis technique is very important to reduce our Type-I error and gives us efficient results for interpretation.

Data transformation technique is one of the remedy to solve this problem of non-normality. Several data transformation techniques are available to normalize data from non-normal form. We can convert our non-normal data in normal form by using proper data transformation technique but it will be also yields mislead results. So, nonparametric methods are the most powerful tests to analyze nonparametric data sets. Friedman suggests common one-way nonparametric tests on factorial experiments which foregoing the examination of interaction effects. So, Friedman's test also not gives us robust results.

In the last decades, a number of new techniques have been proposed for the nonparametric analysis of interactions in factorial designs. They all rank the observations and then perform parametric tests on ranks. The aligned rank tests belong to one class of these. Aligning implies that some estimate of a location (e.g., for the effect on a certain level of a given factor), such as the mean or median of the observation, is subtracted from each observation. These data, thus aligned according to the desired main and/or interaction effects, are then ranked and parametric tests are performed on these aligned ranks.

2. Review of Literature

Rank transformations have appeared in statistics from Sawilowsky, S.S. (1990) [15]. Conover and Iman's (1981) [5] suggests Rank Transform (RT) method on ranks which were averaged in the case of ties, over a data set, and then uses the parametric F-test on the ranks, resulting in a nonparametric factorial procedure. However, Salter, K.C. and Fawcett, R.F. (1993) [14] and

Higgins, J.J. and Tashtoush, S. (1994) [10] subsequently discovered that this process produces inaccurate results for interaction effects which makes the RT method unsuitable for factorial designs. The Aligned Rank Transform (ART) corrects this problems providing accurate nonparametric treatment for both main and interaction effects. Higgins, J.J. and Tashtoush, S. (1994) [10] proposed an aligned rank transform test for interaction. After that many of researchers suggested the Aligned rank transform as a robust method for non-parametric factorial experiments.

3. Methodology

3.1 Usual Parametric Factorial ANOVA

A two-factor factorial design is an experimental design in which data is collected for all

Possible combinations of the levels of the two factors of interest.

$$Y_{ijk}=\mu+\alpha_i+\beta_j+(\alpha\beta)_{ij}+e_{ijk}$$

Where $i = 1... a$, $j = 1,..., b$, and $k = 1,..., n$. Thus we have two factors in a factorial structure with n observations per cell. As usual important assumption is that $e_{ijk} \sim N(0, \sigma^2)$, i.e. error must be independently and identically distributed with the normal distribution.

3.2 Normality Tests

Aderson- Darling test, Shapiro-wilk test, P-P plot, Q-Q plot techniques can be used to test

Normality of the data. Here we give Anderson-Darling test results for datasets.

3.3 Data Transformation Techniques

Transformations are typically performed to stabilize variance, improve normality, Simplify the model. We generally use Log transformation technique, Square root transformation technique and inverse transformation technique to stabilize the error variance and to improve normality of the dataset. Applications of these transformations are based upon the criterion of relation between the mean and variance of the dataset. Here we were check results based upon data using data transformation techniques viz. log, square-root and inverse.

3.4 Proposed Analytical Procedure

Parametric procedures compare mean scores and distributions around these means by

Assigning different numerical values to the obtained measurements thus influences the results. The differing results of parametric methods under monotone transformations raise questions about the validity and reliability of the parametric approach. Alternative to parametric methods, nonparametric methods depend merely on the order of ratings and not on the seemingly arbitrary distribution of numerical values. Different researchers were suggested different tests to analyze main and interaction effects in factorial experiments. Friedman's ranking method does not gives proper results for interaction. The Aligned Rank Transform (ART) procedure was devised to correct this problem. Aligned rank transform gives us proper results for main as well as interaction effects.

3.5 Aligned Rank Transform Method

Step 1: For each main effect or interaction, all responses (Y_i) are "aligned," a process that strips from Y all effects but the one for which alignment is being done. This aligned response

We'll call $Y_{aligned}$.

Step2: The aligned responses are then assigned ranks, averaged in the case of ties, and the new

Response we'll call Y_{art}.

Step3: A factorial ANOVA is run on the Y_{art} responses, but only the effect for which Y was

Aligned is examined in the ANOVA table. Thus, for each main effect and interaction, a

New aligned column ($Y_{aligned}$) and a new ranked column (Y_{art}) is necessary.

4. Numerical Example

A 2^2 factorial experiment from agricultural sector is considered for testing the changes in results according to different tests and different data transformation techniques.

4.1 Parametric ANOVA results

Table1: Analysis of variance for 2^2 factorial Experiment

Source of Variation	df	Sum of Squares	Mean Sum of Squares	Variance Ratio F	Tabulated F	
					At 1% L.O.S	At 5% L.O.S
Block	3	338.69	112.89	1.28	6.99	3.86
Main effect K	1	798.06	798.06	9.07**	10.56	5.12
Main effect P	1	1242.56	1242.56	14.13*,**	10.56	5.12
Interaction effect KP	1	162.56	162.56	1.84	10.56	5.12
Error	9	791.56	87.95	-	-	-
Total	15	3333.43	-	-	-	-

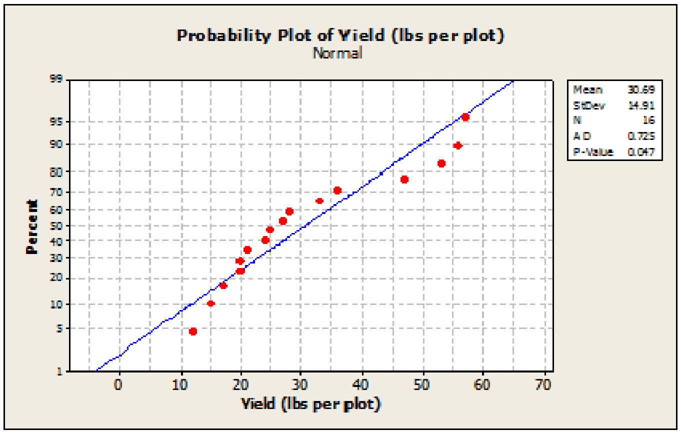
*-significance at 1% l.o.s, **-significance at 5% l.o.s.

From the above ANOVA table, we conclude that main effect K is significant at 5% level of significance and effect P is Significant at 1% & 5% level of significance.

The p-Value in above tests is 0.047 and results conclude that the response is non-normal. So, we have to go for data transformation techniques to normalize response.

4.2 Data transformation results

The data transformation techniques log, square-root and inverse are used to normalize response and response was found to be normal for theses transformation techniques. The parametric ANOVA is run on theses transformed data sets.



Graph 1: Anderson Darling test to test normality of data

Table 2: Analysis of variance table using various data transformation techniques

Transformation technique	Sum of Squares	Sum of Squares	Mean Sum of Squares	Variance Ratio F	Tabulated F	
					At 1% L.O.S	At 5% L.O.S
Log	Main effect K	0.1663	0.1663	8.5559**	10.56	5.12
	Main effect P	0.2491	0.2491	12.8195*,**	10.56	5.12
	Interaction effect KP	0.0063	0.0063	0.3242	10.56	5.12
Square-root	Main effect K	6.3874	6.3874	8.9128**	10.56	5.12
	Main effect P	9.7701	9.7701	13.6329*,**	10.56	5.12
	Interaction effect KP	0.6938	0.6938	0.9681	10.56	5.12
Inverse	Main effect K	0.0013	0.0013	7.3654**	10.56	5.12
	Main effect P	0.0018	0.0018	10.5290**	10.56	5.12
	Interaction effect KP	$1.11E^{-5}$	$1.11E^{-5}$	0.0654	10.56	5.12

*-significance at 1% l.o.s, **-significance at 5% l.o.s.

From the above table, we clearly seen that the main effect K is significant at 5% l.o.s., main effect P is significant at 1% & 5% l.o.s. and the interaction effect is non-significant at both 1% & 5% l.o.s. for log transformation technique results as well as square-Root transformation technique results. The main effects k & P both are significant at 5% l.o.s. and interaction effect is non-significant at both 1%& 5% l.o.s. for inverse transformation technique. Also, the F ratio values are surprisingly vary for all the three effects for different transformation techniques and we cannot confirm which transformation will give better interpretation for our results. So, the nonparametric method will be the best option for nonparametric data.

4.3 Nonparametric test results

Table 3: Aligned Rank ANOVA table

Source of Variation	df	Sum of Squares	Mean Sum of Squares	Variance Ratio F	Tabulated F	
					At 1% L.O.S	At 5% L.O.S
Main effect K	1	81	81	7.31**	10.56	5.12
Main effect P	1	121	121	10.93*,**	10.56	5.12
Interaction effect KP	1	4	4	0.36	10.56	5.12

*-significance at 1% l.o.s, **-significance at 5% l.o.s.

From above table, it is seen that the main effect K is significant at 5% l. o. s and Main effect P is significant at 1% & 5% l.o.s.

5. Conclusion

The results for different tests were considerably varied for this non parametric data set. The Parametric factorial ANOVA Results and the various data transformation techniques applied on original dataset gives rise to variation in F ratio values. Parametric method doesn't gives valid results because of several violations of assumptions of parametric ANOVA and also the differing results of parametric methods under monotone transformations raise questions about the validity and reliability of the parametric approach. So, here we proposed analytical procedure of Aligned Rank Transformation & recommend to go through proper analytical procedure.

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