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**Application development and Consulting Center**

for

**N-Factor ANOVA Calculator**

**Arrangement of Work for Statistical Analysis Tool for ANOVA based Gage R&R**

**Document Revision History**

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# Scope

Arxtron to design a tool that can perform ANOVA based Gage Repeatability & Reproducibility (Gage R&R) given a Comma Separated (csv) log file. The tool must be able to load and display a log file’s data, as well as specify all the parameters necessary to perform ANOVA Gage R&R. The tool must be able to highlight outstanding values (%GRR, PTRatio) based on specified thresholds. The tool must be able to save the current analysis and load it at a later time.

# Definitions

**ANOVA** – ANalysis Of VAriance

**Fixed Factor** – Factor values in dataset reflect the entire range of possible values

**Random Factor** – Factor values in dataset represent a subset of the entire range of possible values

**SS** – Sum of (difference of) Squares

– Degrees of freedom

**MS** – Mean of SS

**F** – A unitless measurement that determines the statistical significance of a factorin the dataset. The critical value is determined based on the degrees of freedom of the factor and total data set, and the significance level (typically set at 0.05). Where F values greater than this critical value means that the factor is significant in affecting the data variance.

**Significance Level (α)** – Used to determine the critical F value

**Variance ()** – A measurement of the amount of spread in a dataset (Eg. How wide the Gaussian Distribution is)

**Standard Deviation ()** – A measurement of the likelihood of how far an individual measurement is away from the mean, where of data, of data, and of data.

**Gage Repeatability and Reproducibility (Gage R&R)** – A measurement of how repeatable (equipment variance ) and reproducible (factor variance ) the results are.

**%GRR** – The ratio between GRR and the total standard deviation of the system, generalized to determines whether a system’s measurements are acceptable, where Good = <10%.

**Upper/Lower Boundary Limit (UBL/LBL)** – Expected high and low limits of a measurement.

**Percentage of Tolerance Ratio (P/T Ratio)** – The likelihood that the variance of the system () contributing to producing a false negative (UBL-LBL).

# Feature Breakdown

## General Interface

The software should launch a small panel featuring Open/Load buttons, where Open looks for .csv extension and Load looks for .sav or .db (depending on save implementation) extensions.

## Load Log Files

When the user selects a csv through the Open menu, a new panel should launch with a table display that includes the entire csv content as string. This table should be able to recognize empty cells when loading the data.

## Specify ANOVA Parameters

The Open panel should also feature a button/list combo for adding/removing certain columns/cells to specify which columns are factors, data, and limits.

For factors and data, it should be able to take a cell selection from the table as the first row, and assume all following rows of the selected column is the factor or data. The list display for each should display the added selection as CnRm:CnR.

For example, if column 5 Row 10 is the cell selected, it would be added to the list as C5R10:C5R.

Optional additional features could include

* A specific end row (Eg. C5R10:C5R20)
* Assuming Rm-1 as the heading and display it as text in the list instead of the column/row designation
* Highlight the selected column as different colours to indicate what the column was added as (Eg. Blue for factors and Yellow for data)
* Adding multiple columns at the same time and being able to recognize columns that have text instead of numbers as non-data
* Specify whether the data is Fixed or Random (depending on calculation implementation)

A separate selector must be available for the upper and lower limits for each of the measurements. This selector must be able to accept both row (Nx1) or column (1xM) as a selection for upper or lower limits. You can assume that the limits added will be in the same order as the selected data columns.

There must be at least 1 factor and 1 data added. And number of upper and lower limits must match the number of data added.

Once all conditions are met, clicking an OK button should launch the ANOVA panel.

## ANOVA Calculations

The ANOVA panel should be launched from the Open panel, or directly from the Load button. Upon launch, it should start calculating all ANOVA values with some form of “Loading” or “Calculating” indication, or simply load in previously calculated values. This should show a table display similar to the existing SQLite based tool’s vANOVA view.

At the very least, this calculator should be able to calculate ANOVA for all fixed factors up to 2 factors. Ideally, the calculator should be able to handle any number of factors (implement using depth first tree?) and a mixed number of fixed and random factors.

Optional additional features could include

* Being able to go back to the Open panel to change selected columns or being able to change the selection directly in the ANOVA panel
* Being able to change whether a selected factor is Fixed or Random

## Value Highlighting

This feature is optional. The ANOVA panel should feature number fields for PTR and %GRR for Good, Warn, NG, where numbers below each threshold is highlighted in Green, Yellow, or Red.

## Save and Load

The ANOVA panel should also have a Save button that saves the current ANOVA values to a CSV, and tie the relationship of the ANOVA values with the log file name in a .sav file AND/OR save the raw data and values as a new .db file that features all the existing views of the current SQLite implementation, except the views are limited to just the number of data fields selected.

In the first case, you can assume that the .sav file is in the same directory as the log and output ANOVA csv files.

# Appendix A – N-Factor ANOVA Generalized Example

This section provides a 3-way ANOVA analysis. The formulas can be generalized to n-way ANOVA, although typically you shouldn’t analyze more than 3 variables in parallel anyways.

## Dataset

Data (random)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| a | b | c | Trial 1 | Trial 2 | Trial 3 |
| 1 | 1 | 1 | 9.8 | 9.813 | 9.78 |
| 1 | 1 | 2 | 10.44 | 10.447 | 10.437 |
| 1 | 2 | 1 | 9.99 | 9.97 | 10.01 |
| 1 | 2 | 2 | 10.54 | 10.576 | 10.54 |
| 2 | 1 | 1 | 10.61 | 10.59 | 10.559 |
| 2 | 1 | 2 | 9.18 | 9.208 | 9.16 |
| 2 | 2 | 1 | 9.66 | 9.708 | 9.662 |
| 2 | 2 | 2 | 10.84 | 10.856 | 10.833 |
| 3 | 1 | 1 | 9.62 | 9.626 | 9.593 |
| 3 | 1 | 2 | 9.98 | 9.954 | 9.987 |
| 3 | 2 | 1 | 10.26 | 10.212 | 10.21 |
| 3 | 2 | 2 | 9.3 | 9.34 | 9.376 |

## Fixed Factor Formulas

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Factor | SS |  | MS | F |  |
| a |  |  |  |  |  |
| b |  |  |  |  |  |
| c |  |  |  |  |  |
| ab |  |  |  |  |  |
| ac |  |  |  |  |  |
| bc |  |  |  |  |  |
| abc |  |  |  |  |  |
| Equipment |  |  |  |  |  |
| Total |  |  |  |  |  |

## Random Factor Formulas

NC = No change

NA = Not applicable

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Factor | SS |  | MS | F |  |
| a | NC | NC | NC | NA |  |
| b | NC | NC | NC | NA |  |
| c | NC | NC | NC | NA |  |
| ab | NC | NC | NC |  |  |
| ac | NC | NC | NC |  |  |
| bc | NC | NC | NC |  |  |
| abc | NC | NC | NC | NC | NC |
| Equipment | NC | NC | NC |  | NC |
| Total | NC | NC |  |  |  |

## Mixed Factor Formulas

If a was random and b and c were fixed

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Factor | SS |  | MS | F |  |
| a | NC | NC | NC | NA |  |
| b | NC | NC | NC |  |  |
| c | NC | NC | NC |  |  |
| ab | NC | NC | NC |  |  |
| ac | NC | NC | NC |  |  |
| bc | NC | NC | NC |  |  |
| abc | NC | NC | NC | NC | NC |
| Equipment | NC | NC | NC |  | NC |
| Total | NC | NC |  |  |  |

## Results (Fixed only)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Factor | SS |  | MS | F |  |
| a | 1.046089 | 2 | 0.523045 | 1027.14 | 0.043545 |
| b | 0.266772 | 1 | 0.266772 | 523.88 | 0.014792 |
| c | 0.048473 | 1 | 0.048473 | 95.19 | 0.002665 |
| ab | 0.225030 | 2 | 0.112515 | 220.95 | 0.018668 |
| ac | 1.293084 | 2 | 0.646542 | 1269.67 | 0.042586 |
| bc | 0.383780 | 1 | 0.383780 | 753.66 | 0.107672 |
| abc | 5.745522 | 2 | 2.872761 | 5641.47 | 0.957417 |
| Equipment | 0.012221 | 24 | 0.000509 |  | 0.000509 |
| Total | 9.020973 | 35 |  |  | 1.187854 |

## Gage Repeatability & Reproducibility

By definition, Gage R&R is the sum of the variance of the equipment, and all operator related factors. But can be generalized to the sum of the variance of any number of parameters.

## Percentage of Tolerance Ratio

## Sources

<https://www.theopeneducator.com>

Measurement Systems Analysis, 4th Edition