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AN INTERNET BASED GAGE R&R AND UNCERTAINTY ANALYSIS SYSTEM

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1. INTRODUCTION

In a world where the gap between the macro and the micro scales is on the increase, measurement and measurement procedures assume significant importance. In an effort to produce high quality products, industries employ state-of-the-art manufacturing techniques. The best manufacturing techniques would be meaningless without being complimented by the best measurement system and procedures in order to get accurate measurement results. The present industrial scenario is such that the measurement process has become increasingly tedious and also subject to a lot of constraints.

Traceability (VIM 6.10 [1]), a requirement for quality standard certification, is the property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties. In order to establish traceability, measurement results must be accompanied by a statement of uncertainty. The theory and computation of measurement uncertainty requires a certain degree of knowledge and expertise and so in most cases, the industry follows a much simpler procedure called gage repeatability and reproducibility (Gage R&R) to represent the total variation in the measurement system. The need for simple tools for estimation of Gage R&R and measurement uncertainty has provided the motivation for us to build an internet based software system for the estimation of Gage R&R and measurement uncertainty.

2. GAGE REPEATABILITY AND REPRODUCIBILITY

The most common method used to estimate variation in the result of a measurement is the Gage Repeatability and Reproducibility study. Gage Repeatability and Reproducibility (Gage R&R) is a statistical concept to determine if a gage or a gauging system is suited to the process under measurement. There are basically a couple of methods that are currently in use namely, the average and range method and the analysis of variance (ANOVA) method.

The average and range method is a simple and easy to compute method and provides us with estimates of repeatability, reproducibility, part variation, repeatability & reproducibility (R&R) and the total variation. The numbers estimated above are raw numbers and they are usually expressed as a percentage of total variation and as a percentage of tolerance to be more meaningful. This method involves multiple parts, appraisers and trials to quantify the total variation of the system.

The other method used to conduct a Gage R&R study is the analysis of variance method. The ANOVA method provides us with all the information as the average and range method and in addition gives information about the interaction between the parts and appraisers. The method is also suited to handle any kind of experimental set-up and gives accurate results. The method is however computationally very intense and requires a lot of calculations and so can be done only with the aid of a computer which is not the case with the average and range method.

2.1 Gage R&R software system

The internet based software system for the estimation of gage repeatability and reproducibility is a two-tier (client-server) architecture system. The client side (front-end) will have the Java enabled web browser through which the user can interact with the system. The server side (back-end) houses all the Java programs written using Java servlets. The way the system works is as follows: the user opens a web browser and sends in a request to the system for a particular action to be performed. The system, upon receiving the request, processes the information and sends the output back to the user in a format which can be viewed on the browser (usually HyperText Markup Language (HTML) format).

The software system is developed based on the principles of the unified modelling language (UML [2]). The requirements of the software system are broken down into a number of small modules called use cases. A use case is a piece of functionality that gives the user a result of value. The schematic shown in Fig. 1 is the collection of use-cases for the Gage R&R software system.

All of the functionalities (use-cases) above have a specific task to perform and a result is obtained from each of these use-cases. The use-case 'Compute parameters for AVRM' is a module which performs functions like computing the average and range of the data set entered by the user. A similar use-case is used for computations using the ANOVA method. Once the initial parameters are computed, the 'analysis' use-case does the measurement analysis. The result of the analysis is the measure of the

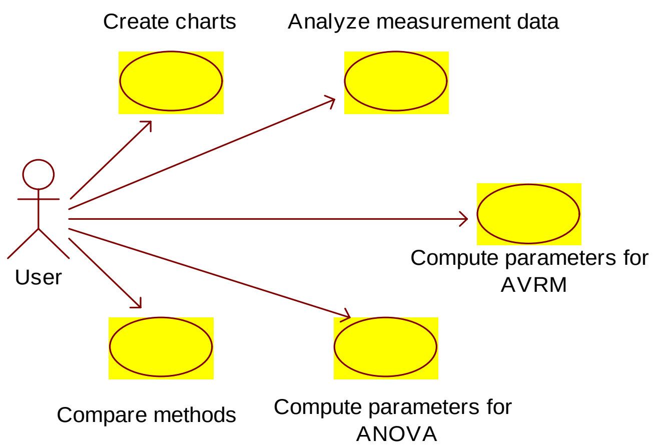


Fig. 1. Use Case Diagram for Gage R&R software system.

repeatability, reproducibility, R&R, part variation and total variation. The ANOVA method, in addition to all of the above parameters, also gives the measure of the interaction between the part and the appraiser. The two methods can be compared to each other and charts can be generated to aid in the detection of errors in the production process. A snapshot of the screen containing the results of an ANOVA analysis is shown in Fig. 2

3. MEASUREMENT UNCERTAINTY

Any measurement made is only a rough estimate of the measurand (particular quantity that is subject to measurement) and is complete only when accompanied by a statement of uncertainty, is the general notion among experts today. Measurement uncertainty is defined as a parameter, associated with the result of a measurement, which characterizes the dispersion of the values that could reasonably be attributed to the measurand. The quality standards (ISO 9000 etc.) require that every measurement be accompanied by a statement of uncertainty. The computation of measurement uncertainty is a complex process as it requires a thorough understanding of the factors influencing the measurement process and the measurement process itself. The procedure for computation of uncertainty is laid out in the 'Guide to expression of uncertainty in measurement,' commonly referred to as the GUM [3].

3.2 Measurement uncertainty software system

The internet based software system for estimation of measurement uncertainty is a three-tier architecture system. It has three layers namely, the front end, the middleware layer, and the back end. The schematic of a three-tier architecture system is shown in Fig. 3. The user can access the system, as before, through a Java enabled web browser. The user sends a HTTP (HyperText Transfer Protocol) request to the server which is the heart of the system. The programs and functions for executing the requests from the user reside in the server. The server is connected to the database by means of Java database connectivity (JDBC). The server processes the information and returns the results in a user-viewable format (HTML).

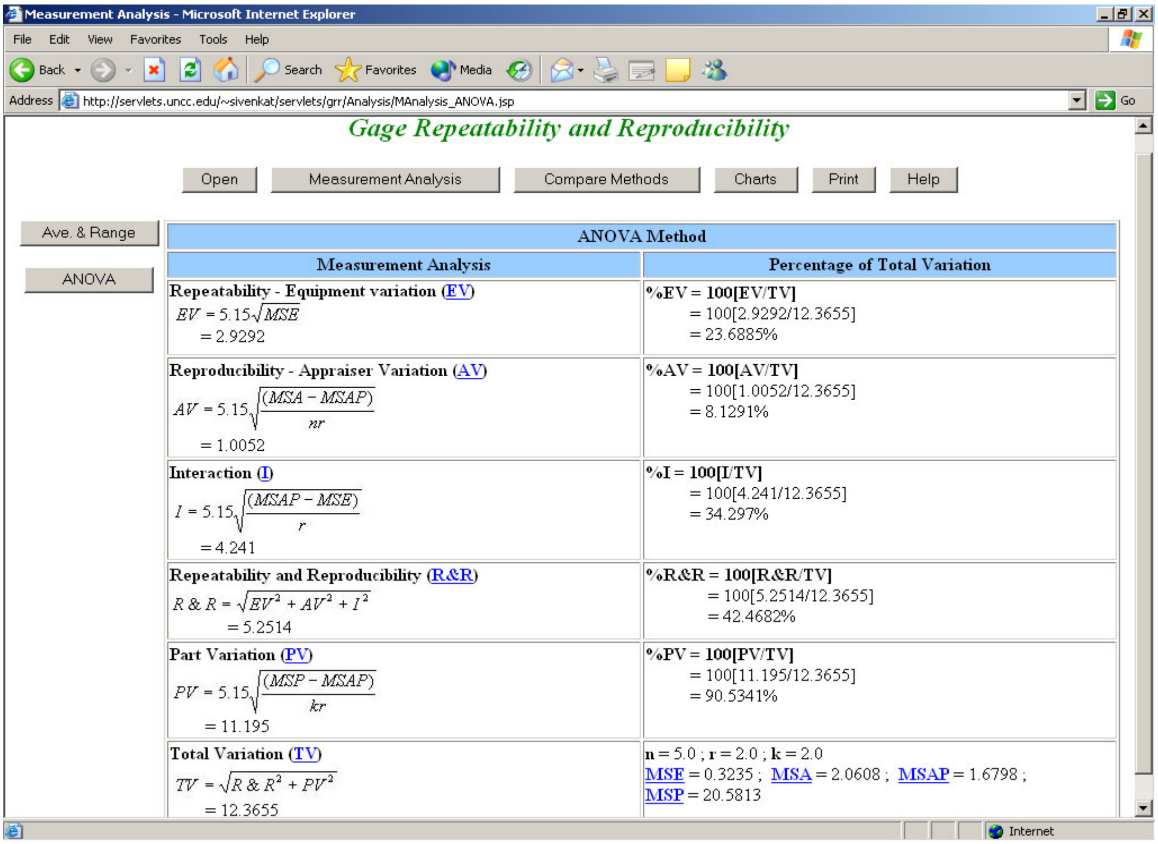


Fig. 2. Snapshot of the measurement analysis screen for ANOVA method

The requirement analysis for the measurement uncertainty is intended to capture all functionalities that are required to come up with an uncertainty budget as laid out in the GUM. The use-cases (functionalities) for the software system are shown in Fig. 4.

The process of creating an uncertainty report using the software system is as follows: The user, before gaining access to the system, needs to create an account by signing-up. The user will have to login to the system for access at anytime. The user, upon logging in, can choose the class of gage that is used for the measurement process from the list of gages given. The user also has the option of creating a new gage class for computing the measurement uncertainty. The user then needs to provide details of the budget parameters which typically include, instrument name, personnel name, nominal value, units etc. This is the first phase of preparing the uncertainty report.

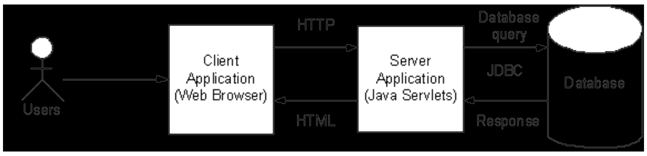


Fig. 3. Uncertainty analysis software system architecture

The second phase involves entering the sources of errors one at a time and specifying parameters like error estimate, distribution, sensitivity coefficients, correlation, degrees of freedom etc. Once all of the errors sources have been entered and the standard uncertainty has been computed for all the errors sources, the combined standard uncertainty and the expanded uncertainty is evaluated using a suitable coverage factor. The final report will have all the budget parameters, information on all of the error sources and the results of the computations as shown in Fig. 5. The user can retrieve uncertainty reports at any point of time as all of the entries are stored in the database. The database is designed using the principles of Structured Query language (SQL) and the tool used was Oracle. The special feature of this software is that it is 'self-learning,' in that it remembers error sources and distributions used for a particular class of gage measurements and provides suggestions to the user on subsequent sessions.

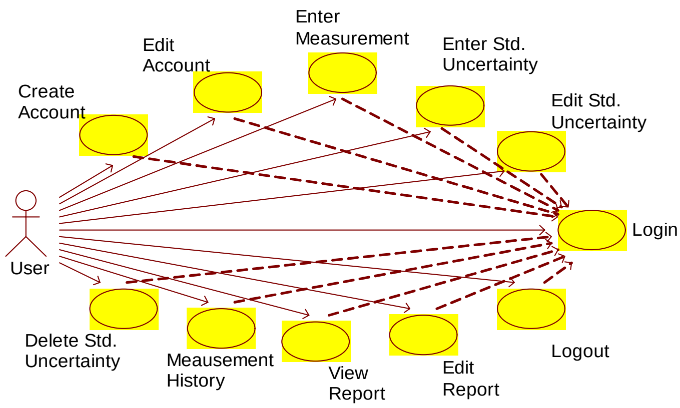
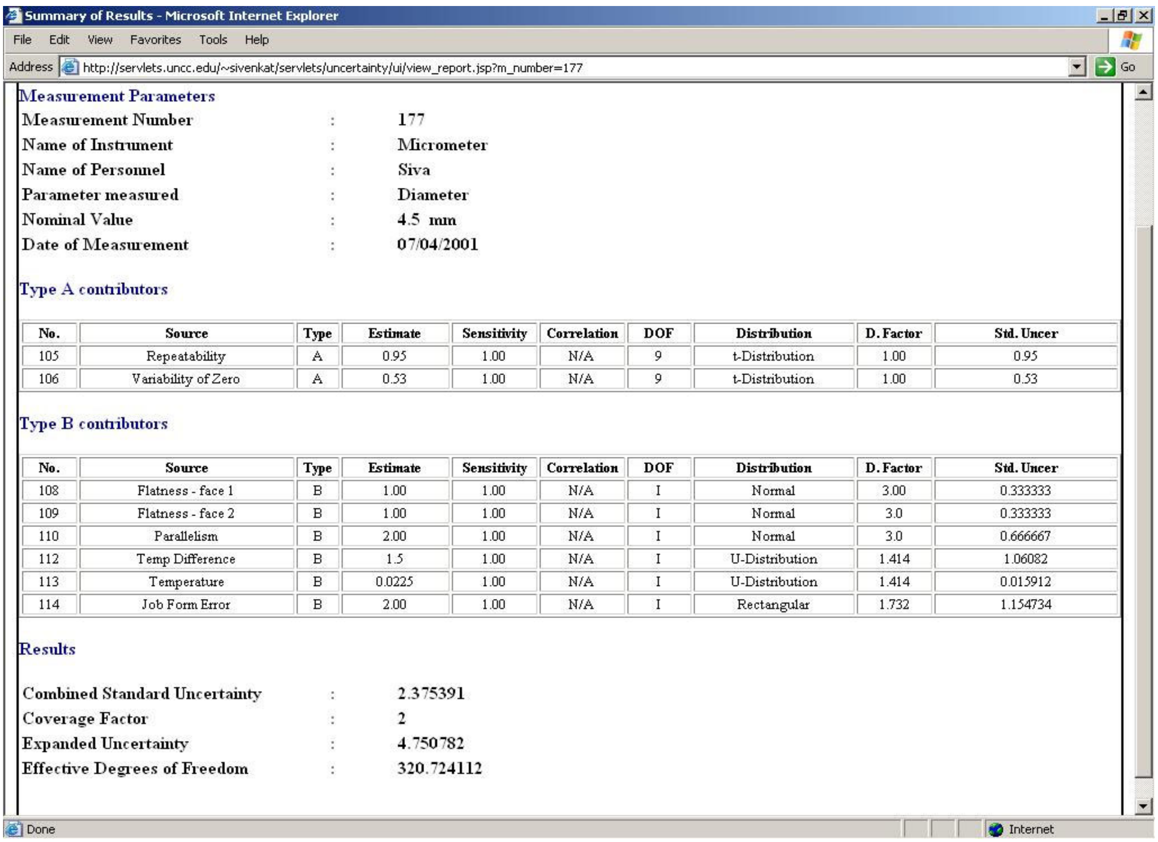


Fig. 4 Use-case diagram for measurement uncertainty software



Measurement Parameters

Measurement Number	:	177
Name of Instrument	:	Micrometer
Name of Personnel	:	Siva
Parameter measured	:	Diameter
Nominal Value	:	4.5 mm
Date of Measurement	:	07/04/2001

Type A contributors

No.	Source	Type	Estimate	Sensitivity	Correlation	DOF	Distribution	D. Factor	Std. Uncer
105	Repeatability	A	0.95	1.00	N/A	9	t-Distribution	1.00	0.95
106	Variability of Zero	A	0.53	1.00	N/A	9	t-Distribution	1.00	0.53

Type B contributors

No.	Source	Type	Estimate	Sensitivity	Correlation	DOF	Distribution	D. Factor	Std. Uncer
108	Flatness - face 1	B	1.00	1.00	N/A	I	Normal	3.00	0.333333
109	Flatness - face 2	B	1.00	1.00	N/A	I	Normal	3.0	0.333333
110	Parallelism	B	2.00	1.00	N/A	I	Normal	3.0	0.666667
112	Temp Difference	B	1.5	1.00	N/A	I	U-Distribution	1.414	1.06082
113	Temperature	B	0.0225	1.00	N/A	I	U-Distribution	1.414	0.015912
114	Job Form Error	B	2.00	1.00	N/A	I	Rectangular	1.732	1.154734

Results

Combined Standard Uncertainty	:	2.375391
Coverage Factor	:	2
Expanded Uncertainty	:	4.750782
Effective Degrees of Freedom	:	320.724112

Fig. 5 Snapshot of an uncertainty report developed using the software system

4. CONCLUSIONS

The software developed will help the metrology user community to develop measurement uncertainty budgets in an easy and simple to comprehend fashion. The application developed is also in compliance with the GUM, which has been accepted as the standard in measurement uncertainty analysis. The software goes by the assumption that the bias errors have been corrected for and the only possible uncertainty component arising out of the bias is the uncertainty due to the correction of bias. The software also attempts to give a reasonable measurement uncertainty estimate for a particular measurement. The correctness of the estimate is dependent on the user's estimations of the uncertainty components.

REFERENCES

[1] International Organization for Standardization, International Vocabulary of Basic and General Terms in Metrology, second edition, 1993.
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[3] I. Jacobson, G. Booch, J. Rumbaugh, "The Unified Software Development Process", Addison Wesley Publications, 1st edition, 1999.

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