Combining standardized approaches to uncertainty analysis

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Is the GUM the only document to consider for UA?

The GUM (JCGM100:2008) does not explicitly mention other approaches than 1st-order uncertainty propagation method:

→ MCMC methods and Bayesian inference are not cited

→ ISO 5725 standard is cited [5] but collaborative methods are not explicitly mentioned, except for a note:

1.4 This Guide provides general rules for evaluating and expressing uncertainty in measurement rather than detailed, technology-specific instructions. Further, it does not discuss how the uncertainty of a particular measurement result, once evaluated, may be used for different purposes, for example, to draw conclusions about the compatibility of that result with other similar results, to establish tolerance limits in a manufacturing process, or to decide if a certain course of action may be safely undertaken. It may therefore be necessary to develop particular standards based on this Guide that deal with the problems peculiar to specific fields of measurement or with the various uses of quantitative expressions of uncertainty. These standards may be simplified versions of this Guide but should include the detail that is appropriate to the level of accuracy and complexity of the measurements and uses addressed.

NOTE There may be situations in which the concept of uncertainty of measurement is believed not to be fully applicable, such as when the precision of a test method is determined (see Reference [5], for example).
Is the GUM the only document to consider for UA?

Since 2008 the Joint Committee for Guides in Metrology (JCGM) produced various Supplements to the GUM.


Is the GUM the only document to consider for UA?

GUM is currently under revision, with the aim of presenting more application examples, and other documents are in preparation.

- Evaluation of measurement data – Supplement 3 to the "Guide to the expression of uncertainty in measurement" – Modelling\(^3\), JCGM 107
- Evaluation of measurement data – Applications of the least-squares method\(^4\).
- Evaluation of measurement data — Supplement 4 to the “Guide to the expression of uncertainty in measurement” – Bayesian methods, JCGM 108
Is the GUM the only document to consider for UA?

Supplement 1 (MCMC method) states that propagation of standard uncertainties is often preferred for routine applications, but that numerical simulation methods are useful to validate the underlying assumptions.

8 Validation of results

8.1 Validation of the GUM uncertainty framework using a Monte Carlo method

8.1.1 The GUM uncertainty framework can be expected to work well in many circumstances. However, it is not always straightforward to determine whether all the conditions for its application (see 5.7 and 5.8) hold. Indeed, the degree of difficulty of doing so would typically be considerably greater than that required to apply MCM, assuming suitable software were available [8]. Therefore, since these circumstances cannot readily be tested, any cases of doubt should be validated. Since the domain of validity for MCM is broader than that for the GUM uncertainty framework, it is recommended that both the GUM uncertainty framework and MCM be applied and the results compared. Should the comparison be favourable, the GUM uncertainty framework could be used on this occasion and for sufficiently similar problems in the future. Otherwise, consideration should be given to using MCM or another appropriate approach instead.
Is the GUM the only document to consider for UA?

The Supplement on conformity assessment is based on a Bayesian approach.

6 Knowledge of the measurand

6.1 Probability and information

6.1.1 In measurements performed as part of a conformity assessment, knowledge of a property of interest (the measurand) is modelled by a conditional probability density function (PDF) whose form depends on available information. Such information always has two components: that which is available before performing the measurement (called prior information) and the additional information supplied by the measurement [38].

6.1.2 The PDF for a property of interest (the measurand) encodes and conveys belief in its possible values, given a particular state of knowledge. A poorly known measurand generally has a broad PDF, relative to the requirements of a conformity assessment, indicating a wide interval of possible values compatible with meagre information. Performing a measurement provides fresh information that serves to sharpen the PDF and to narrow the interval of possible values of the measurand.

6.1.3 The effect of a measurement is thus to update a pre-measurement (or prior) state of knowledge, yielding a post-measurement (or posterior) state of knowledge that includes the measurement data. The rule for this transformation is called Bayes’ theorem and the underlying mathematical framework is known as Bayesian probability theory. In this document the results of this framework are used without detailed development or proof. A considerable literature is available; see, for example, references [4, 5, 16, 26, 27, 39].
Is the GUM the only document to consider for UA?

As a conclusion, the uncertainty propagation method using Taylor 1st-order expansion is the oldest and the most commonly used method in laboratories, but it is one method amongst others.

Other possible methods are numerical propagation of distributions and propagation based on pdf convolution.

Besides, the Bayesian approach is clearly stated by JCGM documents.

Still, the uncertainty framework, concepts and terminology defined by the GUM are acknowledged as the reference.
What about inter-laboratory tests?

What are they used for?

→ define some values of reference (further used for UA)

→ identify factors of influence and quantify effects

→ monitoring results quality (accreditation)

→ demonstration of best claimed uncertainties by national metrological laboratories (national standards)

They are particularly useful when a mathematical model of the whole measurement process is not available (not only in Biology, Chemistry, but also... Hydrometry: site/operator effects).
What about inter-laboratory tests?

They yield estimation of uncertainty on measurement procedures, not on measurement results.

They are used at the start (influence factors) and at the end (validation) of UA on measurement results.

They are guided by different international standards:

→ ISO 17043 Conformity assessment

→ ISO 5725 Uncertainty analysis of measurement procedures

→ ISO 13528 Statistical computations
Bridging the gaps... ISO 21748

ISO 21748:2010
Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation

Introduction

Pour pouvoir interpréter des résultats, il est essentiel de connaître l'incertitude associée aux résultats des mesures. Sans évaluation quantitative de l'incertitude, il est impossible de décider si les différences observées entre des résultats dépassent la variabilité expérimentale, si les individus d'essai sont conformes aux spécifications ou si des lois basées sur des limites ont été enfreintes. Sans information sur l'incertitude, il existe un risque d'estimation erronée des résultats. Des décisions incorrectes prises sur ces bases peuvent entraîner des dépenses inutiles pour l'industrie, des poursuites judiciaires inappropriées ou bien des conséquences néfastes sur la santé ou pour la société.

Bridging the gaps... ISO 21748

ISO 21748 provides guidelines for:

→ assessing measurement uncertainty from interlaboratory test results

→ comparing such results with the MU obtained applying the uncertainty propagation principles

1 Domaine d'application

La présente Norme internationale donne des lignes directrices en vue:

— d'évaluer les incertitudes de mesure à partir de données obtenues lors d'essais interlaboratoires menés conformément à l'ISO 5725-2:1994;

— de comparer les résultats d'un essai interlaboratoires à l'incertitude de mesure (MU) obtenue en appliquant des principes formels de propagation de l'incertitude (voir Article 13).
ISO 21748:2010 is actually based on an uncertainty propagation equation, and allows for uncertainty budgets.

\[ u^2(y) = u^2(\delta) + s^2_L + \sum c_i^2 u^2(x_i) + s^2_r \]

- Uncertainty associated with method bias
- Interlaboratory standard deviation
- Effects not covered, e.g. sampling effects
- Intra-laboratory standard deviation (repeatability)
Bridging the gaps... ISO 21748

ISO 21748:2010
Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation

As a conclusion, ISO 21748 now appears to be the most upstream document as regards the estimation of measurement uncertainties.

This approach seems to be accepted by accreditation organisation, at the international level.