EMRP Call 2011 - Health, SI Broader Scope & New Technologies

Selected Research Topic number: **SRT-n01**
Version: 1.0

Title: Novel mathematical and statistical approaches to uncertainty evaluation

Abstract

The dissemination and use of measurement results, reliable decision-making and conformity assessment require harmonised treatment of uncertainty, which is the key aim of the *Guide to the Expression of Uncertainty in Measurement* (GUM) and its supplements.

The application of existing GUM guidelines is however often challenging and sometimes not possible, for example when accounting for physical constraints, measurements involving regression procedures, and computationally expensive models. Problems are encountered in most areas of metrology in one form or another. Identifying and prioritising such problems for extensions of the GUM are needed to ensure Europe-wide and global harmonisation.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on "Grand Challenges" related to Health, New Technologies & Fundamental Metrology on pages 14-15 and 42-43.

Keywords

Measurement uncertainty, Bayesian inference, regression, inverse problems, conformity assessment, optimal decision-making, partial differential equations, integral equations.

Background to the Metrological Challenges

The GUM and its supplements are published by the *Joint Committee for Guides in Metrology* (JCGM). Existing approaches to uncertainty evaluation in metrology as embodied in the GUM [1] and its supplements (e.g., [2]) are inappropriate for many current metrological applications, uncertainties are often only crudely approximated or omitted, and metrological guidelines exist only for special cases. Evaluating the uncertainty associated with the outputs of the models arising in important applications is often difficult and challenging. There is a danger that in such cases metrologists will resort to individual or thematically isolated approaches. At the international level the need for research in the areas of Monte Carlo methods, regression and inverse problems, and conformity assessment has been identified.

One challenge is to perform reliable uncertainty evaluations where only a limited number of model evaluations are possible owing to the high computational cost of each evaluation. In such cases, which often arise in measurements that are described by continuous models (including partial differential equations and integral equations – such as for turbulent flow and heat conduction), the Monte Carlo approach of GUM Supplement 1 cannot reasonably be applied. The current practice in metrology is either to invest enormous computational effort or to resort to simple sensitivity analysis. In many cases the problem is completely ignored.

There are many metrological applications where it is necessary to estimate parameters or functional dependencies from data obtained in indirect measurements and associate uncertainties with those estimates, e.g., where the measurand is not the observed quantity or where proper use of calibration models for prediction is required. Owing to the absence of generally accepted procedures and guidelines, metrologists often only solve the deterministic inverse problem, resort to simple sensitivity analysis or use crude approximations to evaluate uncertainties.

Robust measurement uncertainties are essential to underpin and ensure effective conformity assessment and decision-making to enable manufacturers and testing laboratories to demonstrate to regulatory bodies and safety authorities the compliance of their results with specifications. Reliable and optimal decision-making is crucial for manufacturers of products, environmental monitoring, dope testing and health and consumer safety. At present some experimentalists overstate measurement uncertainties because they wrongly treat uncertainties as though they were a safety factor. Conversely, others understate uncertainties by ignoring correlations and treating quantities in a measurement as independent when they are not.

The proposal is expected to contain prioritisation of the selected metrology case studies covering a wide field of metrology applications where the anticipated solutions can be presented in a form suitable for efficient knowledge transfer.

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP-Protocol.

The JRP shall focus on the development of novel approaches to measurement uncertainty evaluation, illustrated by appropriate metrology case studies. The mathematical and statistical methods to be developed shall have an underpinning character for a wide field of metrological applications and shall be the basis for future guidelines, software tools and possibly extensions of the GUM. A successful proposal will include partners from a wide range of metrology areas.

The specific objectives are:

1. To identify and prioritise metrological applications in which the GUM and its supplements are not sufficient
2. To develop uncertainty evaluation in computationally expensive systems
3. To develop uncertainty evaluation for inverse problems and regression
4. To develop procedures for conformity assessment and optimal decision-making.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, and standardisation and regulatory bodies, is strongly recommended.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the “end user” community (eg letters of support) is encouraged.

You should detail other impacts of your proposed JRP as detailed in the document “Guide 4: Writing a Joint Research Project”

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies eg ISO and IEC.
- transfer knowledge to the Joint Committee for Guides in Metrology including BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP, OIML and in particular to JCGM Working Group 1.
- transfer knowledge to the metrology community, including Consultative Committees, Regional Metrology Organisations’ Technical Committees and individual NMIs and DIs.
- transfer knowledge to the national and regional accreditation bodies, the legal metrology and conformity assessment sectors and professional societies.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP, and OIML, Evaluation of measurement data — Guide to the expression of uncertainty in measurement, Joint Committee for Guides in Metrology, JCGM 100 (2008)

[2] BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP, and OIML, Evaluation of measurement data — Supplement 1 to the Guide to the expression of uncertainty in measurement: Propagation of distributions using a Monte Carlo method, Joint Committee for Guides in Metrology JCGM 101 (2008)