EMRP Call 2012 – Open Excellence, Industry and SI Broader Scope

Selected Research Topic number: **SRT-i07**
Version: 1.0

Title: Metrology for movement and positioning in six degrees of freedom

Abstract

The use of 6 degrees of freedom (6DOF) positioning systems is becoming more widespread in applications; such as nanometrology (e.g. Atomic Force Microscopy; AFM), industrial metrology (e.g. Coordinate Measuring Machines (CMM), lithography production systems), mechatronics (e.g. transport, aerospace) and robotics, and over measurement ranges from nanometres to metres. However, optimal use of 6DOF systems requires accurate measurement of their position capability, which raises many metrological issues, such as the need for traceable measurements and system validation and calibration. Therefore, new methods for traceable, highly accurate and fast measurement of 6DOF systems are required for dissemination to industry.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on "Grand Challenges" related to Industry & Fundamental Metrology on pages 13 and 39.

Keywords

6 degrees of freedom, nanometrology, positioning, on-site validation, error mapping, interferometry, mechatronics

Background to the Metrological Challenges

Improved positioning control is needed over a wide range of measurements from the nano-scale (metrology frames for AFM), to the micro-scale (CMM, tomography stages), to mechatronics positioning in automotive and aerospace systems, including more general positioning devices (hexapod, goniometer) and finally to even larger scale (space-based) scientific instrumentation. Applications, such as hexapod positioning stages, require precision and accuracy in several, if not all translational and rotational degrees of freedom. Fast manufacturing processes or dynamic applications require simultaneous measurement and control. Sequential alternation between distinct measurement configurations negatively affects down-time in production and hence costs. Therefore, a specific challenge is to achieve precision and high levels of accuracy for multiple measurements of degrees of freedom, such as 6DOF.

Multi-degrees of freedom measurements, such as 6DOF, require multiple systems or complex probe distribution for 3D translation, tilt and roll. Dedicated setups measure transverse motion and straightness in addition to longitudinal translation, but typically require physical exchange of the referencing optics assemblies. Commercially available compact sub-nm resolution multi-channel fibre-coupled Fabry-Pérot displacement interferometry systems currently promise low weight and low thermal load with high precision and accuracy. However, special care has to be paid to the validation of systems e.g. (orthogonal) alignment and mounting stability in order to ensure the accuracy of their measurements. To help avoid such systematic errors the interaction between systems/tools on metrology platforms or manufacturing equipment during validation and calibration should be minimised. Such interactions include weight and thermal load, electromagnetic interference and changes in measurement configurations. However, a careful balance must be achieved, as whilst minimising the required number of interfaces should improve calibration accuracy it will also decrease the number of interfaces and the number of measurements i.e. degrees of freedom possible.

Error mapping is essential for accurate positioning and measurement. In mechatronics, this includes dynamic error budgeting and the consideration of dynamic and thermal deformations. For nanometrology, in particular AFM metrology, point by point error mapping enables the calculation of local uncertainties for a position as well as the calculation of position dependent measurements e.g. surface texture parameters. While point by point error mapping has been demonstrated with metrological AFMs it has not been implemented with non-metrological AFMs, particularly high speed AFMs working at video rate and used for the examination of live processes.

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 metrology for movement and positioning in Six Degrees of Freedom (6DOF) in order to support innovative and enabling technologies for high-tech industries.

The specific objectives are

1. To develop a versatile modular multi-6DOF tool for non-contact, multi-sensor precision measurement methods for the validation and calibration of mechatronic systems in both laboratory test facilities and on-site industrial environments.
2. To develop single-sensor, fast, simultaneous multi-6DOF precision measurement methods with minimal sample perturbation and a single referencing interface.
3. To improve measurement uncertainty for 6DOF to the nanometer range.
4. To develop a detailed error mapping methodology for the characterisation of high speed stages used for nanopositioning, nanomanipulation, nanofabrication and nanometrology.

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs.

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. The available budget for integral Research Excellence Grants is 42 months of effort.

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 (e.g. letters of support) is encouraged.

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the industrial sector, including nanotechnologies, mechatronics (e.g. transport, aerospace) and robotics.

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

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 and includes the best available contributions from across the metrology community. 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.