Title: Multi-sensor metrology for microparts in innovative industrial products

Abstract

Microparts are widespread in innovative industrial products, such as automotive, medical, printing, microelectronic or telecom products. Such products often contain a large number of complex microparts which require highly accurate measurement with ever smaller tolerances. In order to measure the complete 3D geometry of microparts in a robust, precise and traceable manner, advanced coordinate metrology techniques are needed, such as new multi-sensor techniques e.g. novel tactile probes, optical sensors and X-ray Computed Tomography (CT) systems. It's also important to develop methods for combining measured data (i.e. data fusion) from the different sensors used in multi-sensor techniques to produce multi-sensor data sets which can then be used for the dimensional evaluation of microparts.

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 38 and 39.

Keywords

Dimensional metrology, industrial application, microparts, data fusion, computed tomography, optical sensors, tactile probes, intelligent data processing

Background to the Metrological Challenges

Small components i.e. microparts with complex 3D geometries can be found in many industrial products and for these components, an accurate and robust quality control system is required. In order to achieve this, the development of an improved sensor or improved synergetic data acquisition from many different sensors (e.g. tactile probes, optical sensors and CT systems), capable of capturing multiple, complementary information from the same micropart, is needed.

Tactile probes are mostly integrated into high-precision micro-Coordinate Measuring Machines (CMMs). With these machines traceable measurements with uncertainties below 0.25 µm can be achieved. However, the limiting factors for reducing the uncertainties further i.e. to the nanometre level, are the diameter of the tactile probe elements (currently approximately 100 µm is the minimum), and the lack of specialised probes (e.g. star probes or vibrating probes) needed to measure surfaces that are difficult to access. In addition, the interactions between the tactile probes and the micropart surfaces are poorly understood.

Optical sensors (e.g. confocal microscopes) are mostly used for 2½D measurements. With these instruments, axial resolutions in the nanometre-range can be achieved with microparts. However, their measurement range is often limited by the piezoelectric translation stages and measurements are usually not traceable, due to the effect of the workpiece (i.e. micropart) surface characteristics (e.g. slope, roughness, colour, volume scattering) on the measurements. Furthermore, there are currently no appropriate, calibrated reference standards (i.e. standards with ideal standard geometries or workpiece-like reference standards) or theoretical estimations available to quantify the effects caused by the interaction between the workpiece and optical sensor.

In the last few years, industrial CT has been increasingly used for dimensional measurement of both the inner and outer geometry of workpieces, such as the cavities and parts of a mounted assembly. With novel CT instruments spatial resolutions down to one micrometre can be achieved, therefore, this technique could be developed for use with measurements on small precision components such as microparts. However, at present, the measurement errors of most CT systems are considerably larger than those of tactile probes and optical sensors and the traceability of their measurements has not yet been established due to the complex interactions between the CT systems' X-rays and the workpiece.

The data handling and analysis of the large datasets generated by CT systems and optical sensors also requires improvement. Currently, the process is often time consuming and requires operator manipulations which make the measurement results non reproducible. In order to fuse data from different sensors, the registration of the data sets is necessary. In a multi-sensor CMM, the relative position and orientation of the sensors is determined with an appropriate reference standard. However, the diffusely reflecting spheres currently used for sensor registration are often unable to fulfil the requirements of the registration uncertainty. In addition, data sets from sensors with unknown relative positions or orientations are often registered using best fit operations which limit the accuracy of the registration and the subsequent fusion of data sets needs more careful consideration of the quality of the data and improved data fusion techniques.

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 metrology for accurate and traceable 3D measurements of microparts and the dissemination of this metrology to industry.

The specific objectives are

1. To increase the accuracy of micropart sensors by developing methods to characterise and calibrate tactile probes in 3D, as well as producing tactile probes with element diameter < 100 µm and investigating workpiece-probe interactions, friction and wear.
2. To increase the accuracy of micropart measurements by developing traceable methods and reference standards for optical sensors and computed tomography (CT) systems and numerical models for the correction of systematic errors.
3. To develop tools for the reliable determination of task specific micropart measurement uncertainties in an industrial environment.
4. To develop methods for intelligent data processing of the data points generated by optical sensors and CT systems. This should include intelligent filtering, methods for data reduction, automated procedures for the registration and fusion of measurement data from different sensors and correction procedures to reduce measurement deviations.
5. To demonstrate how different probes and technologies for 3D measurements can be combined and used in industry to control and optimise production. This should include end-user demonstrations, training and good practice guides.

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 (eg 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.

- Include input from end-users of micropart products (e.g. automotive, medical, printing, microelectronic and telecom products).

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.