European Partnership on Metrology
Call 2022 – Digital Transformation, Health, Integrated European Metrology, Normative and Research Potential

Selected Research Topic number: **SRT-s12**
Version: 1.0

Title: Application of digital-metrological twins for emerging measurement technology in advanced manufacturing

Abstract

Advanced manufacturing enables novel design and production techniques for industrial products with complex freeform geometries (e.g. turbine blades, medical implants). It also provides fast and contactless measurements for industrial quality control using optical sensors (e.g. in the automotive, machine industry, micromanufacturing sectors). However, current simulation-based methods to determine measurement uncertainty using digital twins in metrology (i.e. digital-metrological twins) in advanced manufacturing, do not fully encompass and hence are not able to be used to model these emerging measurement technologies. Reliable digital-metrological twins representing a wider range of measurement processes, machine tools, and workpieces in industrial applications are needed. As well as (i) the validation of the mathematical models used in the digital-metrological twins, using accurate measurements and (ii) traceable determination of the parameters used in the models, using calibrated measurement standards.

Keywords

Advanced manufacturing, optical sensors, freeform geometries, digital-metrological twins, Industry 4.0

Background to the Metrological Challenges

According to the World Bank, manufacturing industries in Europe have contributed to approximately 14 % - 15 % of Europe's GDP over the last decade. The sector employs almost 30 million people in more than 2 million enterprises and thus, technological advances in manufacturing will support future wealth and prosperity in Europe. However, advanced manufacturing, with its newly emerging measurement technologies, faces challenges as it needs reliable measurement methods to support its development.

Emerging technologies, such as complex freeform geometries are used in advanced manufacturing to provide easier part assembly and more cost efficient and environmentally favourable design of workpieces. The use of optical sensors in advanced manufacturing (e.g. laser triangulation sensors, video sensors, white light distance sensors, chromatic confocal sensors) has also gained in popularity as they can be used to capture data from large areas of a part in a fast, cost-efficient and non-contact manner.

Besides the use of freeform geometries and optical sensors, current trends in advanced manufacturing include the use of digital twins. The original concept of digital twins was put forward in the early 2000s by NASA. A digital twin is a virtual model designed to accurately reflect a physical object or system. The digital twin can span the object's lifecycle and is updated from real-time data from sensors fitted on the object being studied. Thus, the quality of the results from a digital twin are dependent upon the accuracy of the input measurements. Digital twins use simulations, models and machine learning to help with decision-making and can be used in manufacturing for the evaluation of product quality, time and cost savings and to support more environmentally friendly production.

Digital-metrological twins are similar to digital twins but are used for simulation-based uncertainty evaluation. It is, therefore, critical that the underlying models for the digital-metrological twin are validated using accurate measurements and that the parameters for the models are determined in a traceable manner, e.g. using calibrated measurement standards. Although there has been an increase in the use of digital twins in industrial applications within Europe, over recent years, more work is needed. First attempts have been made in the development of digital twins for optical sensors and a number of model-based approaches have been developed for determining measurement uncertainty in devices, machine tools and measurement processes. But further work is urgently needed as current digital twins do not consider all the different types of sensors used or the system influences in advanced manufacturing.

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 protocol.

The JRP shall focus on the development of digital-metrological twins for emerging measurement technology in advanced manufacturing.

The specific objectives are

1. To determine the measurement uncertainty sources attributed to complex freeform geometries, and to develop accurate mathematical models for use in digital-metrological twins of them. This should include the (i) evaluation of the developed digital-metrological twins, (ii) the experimental comparison of the measurement deviations of freeform geometries to established prismatic measurement standards, (iii) the creation of appropriate virtual reference artefacts (i.e. 'softgauges') based on simulations of representative freeform measurement standards.
2. To evaluate the behaviour and inherent properties of at least 3 different types of optical sensors (e.g. interferometric, chromatic white light sensors, line scanners) integrated into coordinate-measuring machines (CMMs) and/or machine tools. In addition, to determine the influence of surface characteristics, surface tilt and curvature on the interaction between optical sensors integrated into CMMs/machine tools and freeform and prismatic geometries. Using the data collected, establish reliable mathematical models for the at least 3 different types of optical sensors integrated into CMMs/machine tools and use these models in digital-metrological twins to improve both the measurement uncertainty evaluation and advanced manufacturing processes.
3. To develop methods for the traceable parametrisation of models used for measurement uncertainty evaluation in digital-metrological twins. This should include the identification of suitable physical standards and measurement procedures for the parametrisation of digital-metrological twins for optical measurements on freeform geometries. In addition, to development of parametrisation strategies for (i) dimensional freeform geometry measurements (optical and tactile) and (ii) for measurements incorporating optical probing systems (freeform and prismatic geometries).
4. To use the digital-metrological twins developed in Objectives 1-3, optimise their performances for economically efficient application in advanced manufacturing. This should include case studies comparing optical and tactile measurements using both freeform geometries and prismatic parts for post-process and in-process inspection. The results of the case studies should be used (i) to verify the use of the digital-metrological twins for reliable uncertainty evaluation in advanced manufacturing and (ii) to produce good practice guidelines for the use of digital-metrological twins in advanced manufacturing.
5. To demonstrate the establishment of an integrated European metrology infrastructure and to facilitate the take up of the technology and measurement infrastructure developed in the project by the EMN Advanced Manufacturing, measurement supply chain, standards developing organisations (e.g. ISO TC 213, ISO TC 39, VDI/VDE GMA) and end users (e.g. the automotive, machine industry, micromanufacturing, renewable energy and medical sectors).

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 work, the involvement of the larger community of metrology R&D resources both within and outside Europe, plus engagement with existing European research infrastructures and European Partnerships is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry and end users.

Proposers should establish the current state of the art and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP project IND62 TIM and EMPIR project(s) 17NRM03 EUCoM, 17IND08 AdvanCT, 19ENG07 Met4Wind and 20IND07 TracOptic and how their proposal will build on those.]

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.9 M€ and has defined an upper limit of 2.6 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 25 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the ‘end user’ community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the ‘end user’ community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Develop an integrated self-sustaining European metrology infrastructure,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to advanced manufacturing sectors, including the automotive, machine industry, micromanufacturing, renewable energy and medical sectors.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of the Partnership to develop a coherent approach at the European level in the field of metrology and include 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 EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

Time-scale

The project should be of up to 3 years duration.