

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. It also supports the increasing demand for fast and contactless measurements in industrial quality control using optical sensors. A major driver of innovation for industrial processes is digital transformation and includes measurement techniques using digital metrological twins (D-MTs). However, existing simulation-based methods to determine measurement uncertainty using D-MTs cannot currently meet the developments in advanced manufacturing. There is also a metrological need to develop reliable models, suitable parameterisation methods and guidance for traceable measurements of complex freeform geometries and the use of optical sensors in coordinate metrology. Only by addressing these needs can Europe support sustainable innovation in advanced industrial applications.

Keywords

Advanced manufacturing, optical sensors, freeform geometries, measurement uncertainty, digital-metrological twins, digital transformation, 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 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. They are also suitable for measuring delicate parts which cannot be probed through tactile measurements. The rapidly growing number of machines which use contactless sensors means that models that cover their numerous error sources are urgently needed.

Besides the use of freeform geometries and optical sensors, current trends in advanced manufacturing include the use of digital twins. 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. Thus, the quality of the results from a digital twin are dependent upon the accuracy of the input measurements. D-MTs are similar to digital twins but are used for simulation-based uncertainty evaluation. Therefore, it's critical that the underlying models for the D-MT are validated using accurate measurements and that model's parameters are traceably determined, e.g. using calibrated measurement standards. Although there has been an increase in the use of digital twins and D-MT in industrial applications within Europe over recent years, more work is needed. First attempts have been made to develop digital twins for optical sensors and model-based approaches have been developed for determining measurement uncertainty in devices, machine tools and measurement processes. However, these digital twins/D-MTs do not consider all the different types of sensors used in advanced manufacturing or the system's influences.

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 freeform geometries, and to develop accurate mathematical models for use in D-MTs. This will include the (i) evaluation of the D-MTs, (ii) the experimental comparison of the measurement deviations of freeform geometries to prismatic standards, and (iii) the creation of appropriate virtual reference artefacts for representative freeform standards.
2. To evaluate the behaviour and inherent properties of at least 3 different types of optical sensors integrated in coordinate-measuring machines and/or machine tools. This will include the determination of the influence of (i) surface characteristics, (ii) surface tilt and (iii) curvature on the interaction between the optical sensors for freeform and prismatic geometries, as well as the development of reliable mathematical models for D-MTs.
3. To develop methods for the traceable parameterisation of models used for measurement uncertainty evaluation in D-MTs. This will include the identification of suitable measurement standards and procedures for the parameterisation of D-MTs and the development of parameterisation strategies for (i) freeform geometry measurements and (ii) for optical sensor measurements.
4. Using the D-MTs developed in Objectives 1-3, to optimise their performance for economically efficient application in advanced manufacturing. This will include case studies comparing optical and tactile measurements using freeform geometries and prismatic parts in order to (i) verify D-MT application and (ii) to produce good practice guidelines for D-MT use.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the EMN Advanced Manufacturing, the 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. 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 – both through project steering boards and participation in the research activities.

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 EMPIR projects 15IND62 TIM, 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 2.3 M€ for this project.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 35 % 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,

- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the advanced manufacturing, 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.