EMPIR Call 2020 – Fundamental, Industry and Normative

Selected Research Topic number: **SRT-i09**
Version: 1.0

Title: Dynamic applications of large volume metrology in industry of tomorrow environments

Abstract

Large volume metrology (LVM) is key to many high value industries where the EU is globally competitive. It is an enabler for evolving from repetition-based automation to self-automated manufacturing in virtualised factories where cloud-computing and artificial intelligence (AI) implement coordinated cyber-physical systems with high reconfigurability. The goal of this project is to extend LVM to highly dynamic applications by researching, e.g. real-time 6DoF feedback to robotic systems, affordable high-speed photogrammetry systems, IoT-based architecture needed for self-automation, methods for rapid machine qualification and compensation as well as high availability distributed LVM systems in reconfigurable environments with line-of-sight constraints.

Keywords

Coordinate metrology; large volume; aerospace; automotive; robotics; machine tools; performance verification; traceability; reference data and algorithms; laser tracker, photogrammetry, Industry 4.0, Industry of Tomorrow, Internet of Things, IoT, Factory of the Future, FoF

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Background to the Metrological Challenges

Traditional automated production systems with limited metrological traceability are struggling to meet the demands of reconfigurable manufacturing approaches in Industry 4.0 and Factory of the Future (FoF). One way to address this problem is to switch from rigid automation schemes to cyber physical schemes that are based on flexible assembly/manufacturing paradigms and linked to intelligent planning/coordination algorithms effectively providing self-automation. Large volume metrology (LVM) instruments enable measurement data to provide the digitizing interface to virtual factory and virtual machine models, connecting the real physical world to the word of AI by providing a virtual, metrology-based reference frame ('metric'). Previous research (e.g. from EMPIR project 17IND03 LaVA, as well as 17IND14 Met4FoF and EMRP project LUMINAR*)* led to significant advances in LVM. However, the extremely harsh and changeable industrial environments with severe line-of-sight constraints and reconfigurability (e.g. AGVs, robots) still present significant challenges such as dynamic 3D reference information with low latency, low uncertainty and high data rate from LVM tools. Concurrent progress in IoT technologies requires their integration and potential benefits to be included in any research domain relying on complex computation.

Computational resources of LVM instruments are set to increase due to the more sophisticated dynamic capabilities as well as the increased data resolution needed for image processing. Scalable high-performance computing supported by dedicated, cloud-based infrastructures represent future enabling technology for distributed measurement systems and would avoid massive costs of computational resources when expanding the number of entities per volume covered, and would facilitate verification, uncertainty analysis and certification of systems through a centralized, server-based deployment of common metrology algorithms. The current commercial state of the art in 3D are laser trackers, typically achieving ~10 µm accuracy at a few metres range, increasing to hundreds of µm at full range. Trackers also represent the best dynamic capabilities as they can scan single points at up to 1 kHz but with compromised accuracy. However, tracker dynamic capability slows to < 100 Hz when using multi-axis single point probes and to < 1 Hz for measuring multiple targets.

End users require LVM techniques that can be applied in dynamic scenarios. Techniques based on novel/cheap sensors, high-accuracy photogrammetry and absolute distance 3D coordinates at long ranges applicable in harsh environments have been developed. However, requirements for better dynamics, scalability and cost needed for self-automating systems and paradigms have since been significantly increased and the techniques need to be refined (e.g. to compensate the kinematic inaccuracy of robotic platforms).

Currently, photogrammetry systems can handle hundreds of targets simultaneously, but accuracy is limited to ~1 in 10^{-5}. Moreover, accuracy and frame rate are naturally competing due to the computational complexity increasing with imaging resolution.

LVM plays a role in future assembly and production scenarios within the frameworks of the FoF and Industry 4.0. The dynamic application of LVM instruments in closed control loops of cyber physical systems requires an *ab initio* architectural design accounting for true dynamic requirements. Such a design must include communication requirements based on bandwidth and latency as well as the uncertainty-driven assignment of LVM instruments in dynamic scenarios.

Currently machine tool calibration in LVM is time-intensive and relies on a dedicated calibration process with static machine positions. Dynamic approaches for machine tool calibration are yet to be transitioned into industrial practice due partly to elevated costs and complex measurement setup. LVM relies heavily on optical systems which all suffer from line-of-sight issues, especially when using high accuracy multilateration principles. Fast algorithms to predict loss of target tracking based on trajectory and to then perform recovery with sufficiently low uncertainty are needed.

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 traceable measurement and characterisation of large objects to underpin the industrial adoption of large volume metrology.

The specific objectives are

1. To develop Frequency Scanning Interferometry-based techniques for high-performance data analysis capable of (i) tracking at least 3 targets at speeds of up to 150 mm/s with quantified position uncertainty (ii) updating data at a rate of 100 Hz to enable input to closed-loop 6DoF robotic controls for trajectory correction (iii) reducing latency of the processing electronics / algorithms to a minimum.
2. To develop low cost photogrammetry-based metrology systems for very large volumes with elevated dynamic capability (up to 10 m/s) and high frame rate (> 100 Hz) capable of(i) tracking large numbers of mobile entities (e.g. AGVs, drones and mobile robots) across the entire factory (ii) allowing adaptive real time synchronization of virtualised and real factories for cloud-based coordination of complex automation systems.
3. To design and produce an IoT-based architecture to integrate cooperative LVM systems with reconfigurable, self-automating processes in the FoF. The architecture should (i) integrate methods for tracking data integrity in addition to conventional traceability, (ii) include uncertainty models for dynamic coordinate measurements for automated assignment of metrology resources to dynamic automation platforms (e.g. robots), (iii) provide a framework for deducing communication requirements (latency, bandwidth) from metrology based cyber physical manufacturing systems.
4. To develop equipment, models and associated strategies for both;
    a. dynamic performance evaluation/error compensation of medium to large machine tools (5 m^3 - 50 m^3) capable of reducing measurement times by 20 % without the need for stationary measurement locations and to allow in-process machine behaviour to be investigated
    b. automated, dynamic reconfiguration of distributed LVM systems capable of reacting to the visibility and uncertainty constraints of factory environments.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (NMIs and DIs), standards developing organisations (ISO) and end users (aerospace, automotive and energy industries). The tools developed in the project should have an industrial application and knowledge should be appropriately transferred to the relevant end users.

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 EMRP project IND53 LUMINAR and EMPIR project 17IND03 LaVa and how their proposal will build on those.

In addition, proposers should interact with EMPIR project 19NET01 AdvManuNet during the development of their proposal and this should be reflected in the proposal.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded 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,
- Transfer knowledge to the aerospace and automotive 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 EMPIR 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.