Title: Traceable machine vision systems for digital industrial applications

Abstract

Machine vision systems (MVSs) are crucial to many high-value industries where Europe is globally competitive, and to the European objectives in terms of digital transformation and green deal. But for these systems to achieve their full potential, further work is needed. Proposers addressing this SRT should establish the traceability of existing and newly developed MVSs combined with other measuring devices, develop digital twins (DTs) of MVSs based on data and physical driven models, and implement robust matching and analysis algorithms for large amount of recorded raw data. Additionally, the applicability of the developed methods and tools should be demonstrated through case studies and scenarios covering multiple industrial applications.

Keywords

Traceability, dimensional metrology, machine vision system (MVS), digital twin (DT), dense matching algorithm (DMA), photogrammetry, uncertainty budget

Background to the Metrological Challenges

The machine vision market was valued at ~13 billion Euros in 2021, and it is expected to grow at an annual rate of ~7 % from 2022 to 2030, driven by an increasing demand for quality inspection and automation in different industrial set ups. Additionally, the need for vision-guided robotic systems across the automotive, food, pharmaceutical and chemical, and packaging segments is expected to fuel the growth of this market.

As quality assurance and inspection become increasingly important towards digital transformation (i.e. Industry 4.0 and the EU green deal), MVSs are used more widely in dimensional quality, structural quality, surface quality and operational quality. As such, the availability of traceable metrology for MVSs at NMIs/DIs becomes indispensable. Currently, calibration and measurement methods which enable to evaluate the uncertainty associated with the measurement of known influence factors, and approaches to identify additional contributions to measurement uncertainty are still lacking. These are essential to optimise performances, allow validation, and ensure metrologically reliable results, which could be enhanced through DTs based on physical or/and data driven models. Nevertheless, the number of contributors addressed, and the methods used for their inclusion in DT models are currently very limited. For every developed DT, verification and validation are fundamental.

ISO 10360-13:2021, published after the German standard VDI/VDE 2634, addresses the tractability of optical 3D coordinate measuring systems. Nonetheless, the “Mise-en-Practique” of the ISO at NMIs and industry is still ambiguous. Most of proposed protocols for the characterisation of imaging are based on well-known special objects with canonical shapes and the existing general concept of “measurement traceability” adopted in the field of tactile 3D measurements is usually applied, even if it is inappropriate for 3D imaging. It is a limited view on the complexity of the whole problem because all contributions to measurement uncertainty must be analysed, including the intrinsic, extrinsic, distortion, optical and physical parameters. This requires the development of supplementary material standards with complex shapes to guarantee the traceability of MVSs in industrial scenarios. including both macroscale and microscale structures. Validated DT environments, currently inexistent for MVSs, could be useful for scan parameter adjustment, shutter time and detailed uncertainty evaluation.

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 machine vision systems for digital industrial applications.

The specific objectives are to:

1. Establish the traceability of existing and newly developed industrial MVSs used in i) dimensional quality, ii) surface quality, iii) structural quality, and iv) operational quality. This should include the development of appropriated material standards with canonical and complex shapes, calibration strategies, traceable identification of MVSs parameters, and uncertainty budgets. Additional contactless tracking systems for improving the positioning knowledge of the MVSs in the working volume shall be considered.
2. Develop DTs of selected and newly developed MVSs through physical models and/or computational models applying AI driven methods, and to predict their responses in analysing systematic errors, as well as to obtain the optimal measurements strategy in the shortest cycle time. Additionally, to develop approaches for the validation of the DTs, including robust methods (e.g., softgauges) for the verification of the models, and statistical procedures for the assessment of differences between measurements of calibrated standards and corresponding data from their virtual counterpart.
3. Implement methods for quantifying the uncertainty of the developed DTs for MVSs. This should require the inclusion of dynamical influences in the models and continual updates (calibration and enrichment) of the underlying models based on fresh data. A procedure for the selection of appropriate MVSs for a given industrial application should be proposed.
4. Investigate and evaluate novel methods and algorithms for dense image matching of multiple recorded images, using softgauges. The algorithms should exploit external knowledge provided by i) physical markers, ii) contactless tracking systems, iii) precise positioning systems (e.g. industrial robots and human-robot collaborative environment), and iv) intrinsic features of the scene. Filtering processes, which are crucial for eliminating outliers, unwanted reflections, shadows, parasitic light, and reducing noises from the recorded raw datasets and images shall be considered. Additionally, robust algorithms should be developed and validated for analysing the full 3D reconstruction and uncertainty budgeting.
5. To facilitate the take up of the technology, good practice guides and measurement infrastructure developed in the project by the EMN for Mathematics and Statistics, (MATHMET), the EMN for Medicine (TraceLabMed), the EMN for Advanced Manufacturing (AdvManu), the measurement supply chain, standards developing organisations (ISO/TC 213 and ASTM Committee E57), and end users (manufacturers from the automotive, food, pharmaceutical and chemical sectors). This should include the demonstration of the practical application of the developed technology in multiple industrial applications.

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.

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 Industry 4.0 sector.

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.