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Special Session
“Future topics in metrology”

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Summary:
Technological developments in industry and society result almost directly in novel requirements for metrology. This special session highlights a few of such *future topics,* presented by young scientists. The session focuses on novel developments and topics arising from the digital transformation in industry and society. This contains NMI-level calibration for and application of MEMS sensors; semantic data management and ontologies in sensor networks; deep learning for inverse problems in form metrology; uncertainty evaluation in machine learning.

Keywords: metrology; digitalisation; MEMS sensor; sensor network; deep learning; machine learning

Motivation

Many recent advances in industrial measurements can be related to digital transformation. An example is the increasing use of networks of sensors, so called “smart sensors” or MEMS sensors instead of single reference measuring instruments in industrial applications. The resulting large amounts of measured data, lack of calibration and complexity of the corresponding mathematical models require novel concepts from metrology regarding traceability and reliability. This session provides a brief look into some of the aspects, metrology institutes have to address in the very near future:

1) MEMS sensors and other sensors with digital-only output, as well as sensors with built-in pre-processing are challenging when it comes to calibration traceable to the SI.
2) Vocabulary, semantic data and ontologies are becoming much more relevant for metrology, when data and information is being processed by algorithms automatically.
3) Uncertainty evaluation in the area of machine learning is a topic of rapidly growing importance as such methods are increasingly applied in the analysis of measured data.
4) Deep learning for complex measurement tasks is becoming a standard tool in the data science toolbox, despite basic questions regarding reliability, transparency and confidence remaining an open topic of research.

These topics will be covered based on actual current research carried out at the German national metrology institute Physikalisch-Technische Bundesanstalt (PTB).

Topics and speakers

Semantic Information in Sensor Networks

Self-describing sensors and measurements are a key component to establish (semi-)automated data analysis in the context of Industry 4.0.

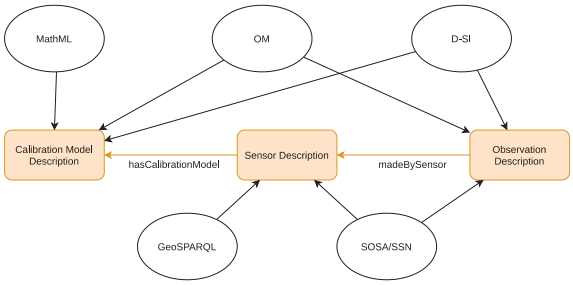

Figure 1 Outline of a concept to link different sources of semantic information

By mapping concepts from existing knowledge bases into a coherent ontology, metrological requirements of sensor and measurement descriptions are satisfied. Use cases considered for this ontology cover sensor networks, network topology, network robustness, information fusion, calibration models for dynamic uncertainty, correct metrological representation and implementation performance.

This topic will be presented by Maximilian Gruber, PhD student working in a research project with the aim to bring metrological principles into RAMI 4.0 and Industry 4.0.

Propagation of uncertainty for an Adaptive Linear Approximation algorithm

In machine learning, a variety of algorithms are available for feature extraction. To obtain reliable features from measured data, the propagation of measurement uncertainty is proposed

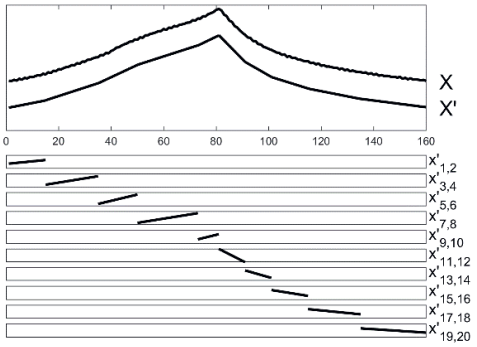

Figure 2 Approximation X' by mean values (uneven indices) and slopes (even indices) of ten segments deter-mined by ALA.

here in line with the Guide to the Expression of Uncertainty in Measurement (GUM).

Recently, methods for the discrete Fourier and Wavelet transform have been published. Here, the Adaptive Linear Approximation (ALA) as a further complementary feature extraction algorithm is considered in combination with an analytical model for the uncertainty evaluation of the ALA features.

This topic will be presented by Tanja Dorst, PhD student working in a European metrology research project with the aim to provide measurement uncertainties for the complete data lifecycle in Industry 4.0.

Deep Neural Networks for optical form measurements

Deep neural networks have been successfully applied in many different fields like computational imaging, medical healthcare, signal processing or autonomous driving. We demonstrate in a proof-of-principle study that also optical form measurement can benefit from deep learning.

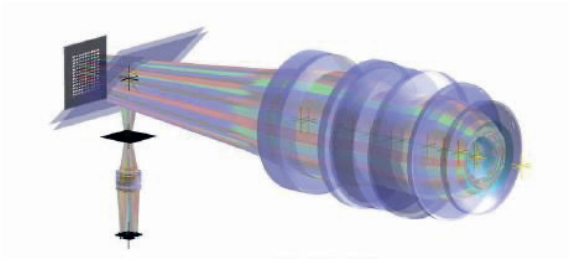

Figure 3 Schematic of the tilted-wave interferometer without reference arm.

Therefore, a data-driven machine learning approach is considered for solving an inverse problem in the accurate measurements of optical surfaces. The approach is developed and tested using virtual measurements (simulations) for the tilted wave interferometer with known ground truth.

This topic will be presented by Lara Hoffmann, PhD student working on the assessment of deep learning methods for solving complex measurement problems.

Dynamic calibration of digital sensors

For the processing of time-dependent data streams (e. g. dynamic measurement for monitoring vibration) an exact knowledge of the temporal relations is necessary. This is of particular importance when the measuring instrument is to be calibrated for dynamic measurements, because this requires traceable measurements of amplitude and phase values.

One approach is using a GPS signal for time stamping the calibration signals in the calibration experiment. To this end, a custom-designed microcontroller board with custom drivers have been developed at PTB. This enables traceable dynamic calibration for sensors with digital-only output.

This topic will be presented by Benedikt Seeger, PhD student working in a European metrology research project with the aim to provide traceable measurement data in Industry 4.0.