Metrology for Trustworthy digital twin of a 3D robotic scanning system

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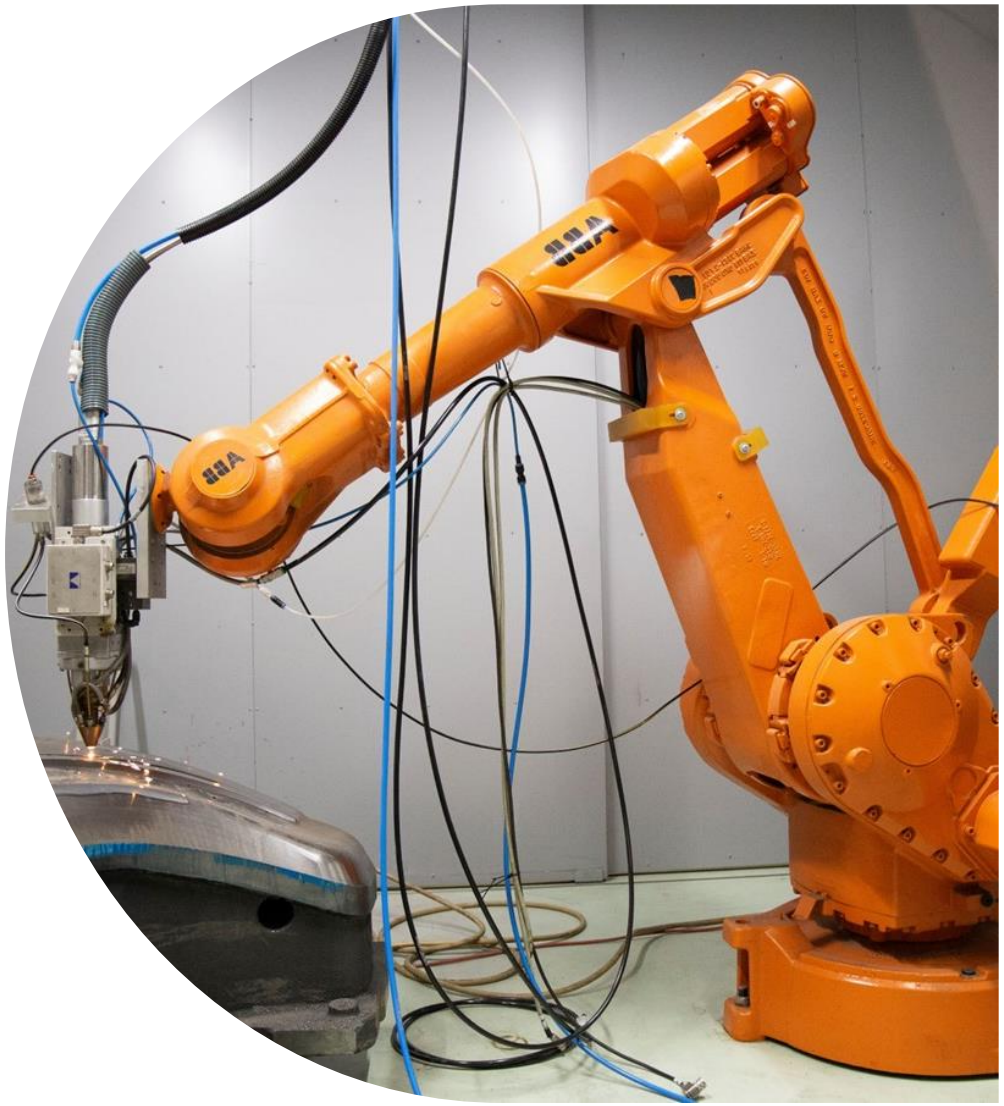
3D METROLOGY CONFERENCE

Loughborough, Loughborough University
2024

MiDiT

OUTLINE

- FRAMEWORK
- DEVELOPMENT OF THE TRACEABLE DIGITAL TWIN
- FUTURE WORKS



About TEKNIKER and IDEKO

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INSPECTION AND MEASURING

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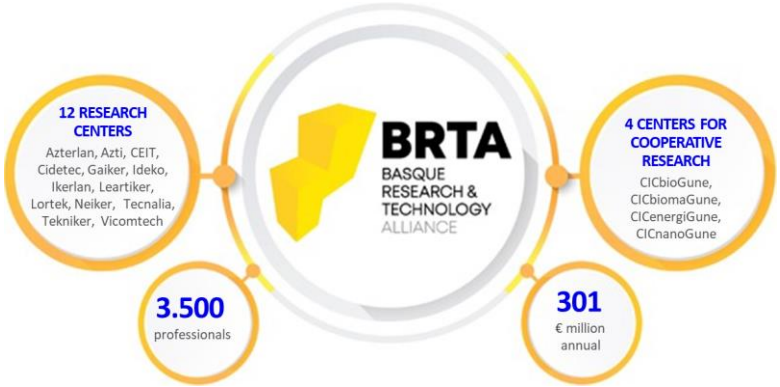
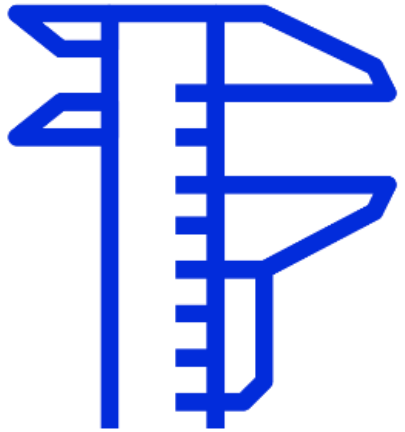


DYNAMICS & CONTROL

MANUFACTURING PROCESSES

ICT & AUTOMATION

DESIGN & PRECISION ENGINEERING



FRAMEWORK

FRAMEWORK

DIGITALISED WORLD: Importance of modeling and simulating real-world processes in a computer is rapidly increasing.

DIGITAL TWINS: Simulation models that accurately replicate physical systems and their characteristics in a virtual environment. DTs also include A dynamic exchange of information between the virtual side and the real side.

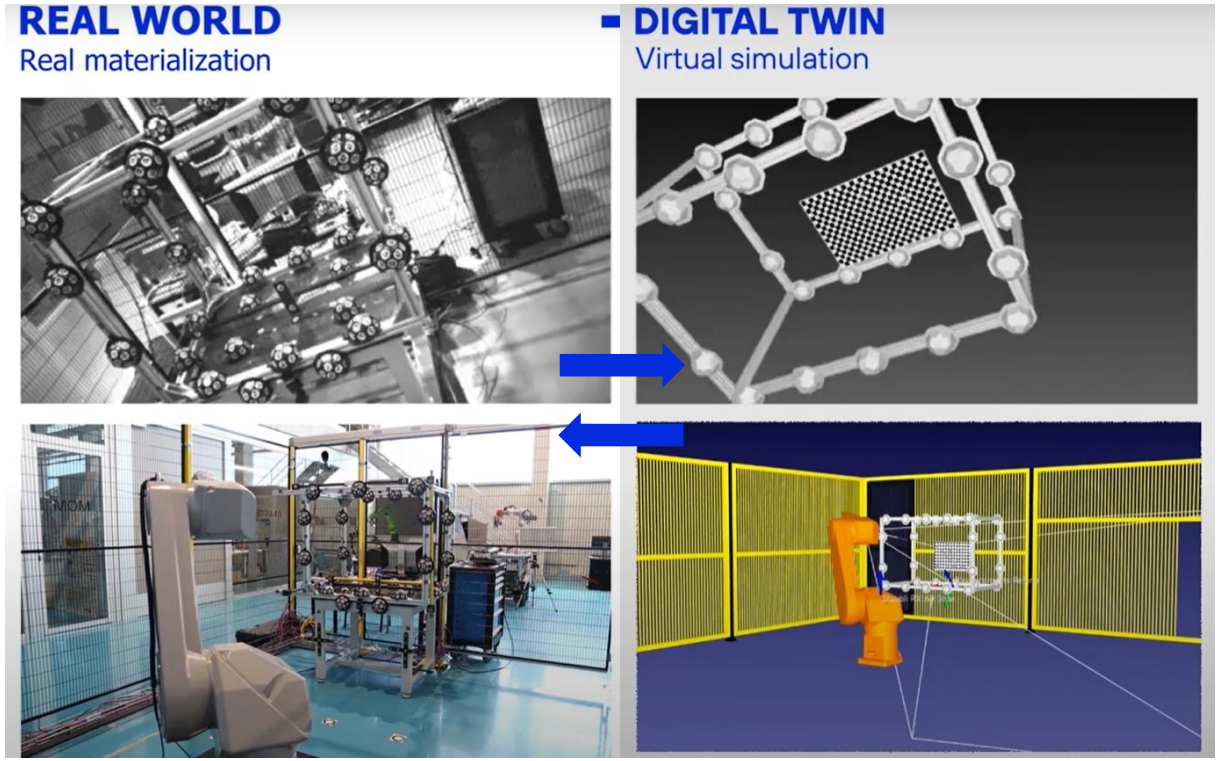
METROLOGY TASK: Rules to ensure confidence in simulation results so that they can be used in a similar way as, or in conjunction with, real measurements.

A BRIEF REMINDER:

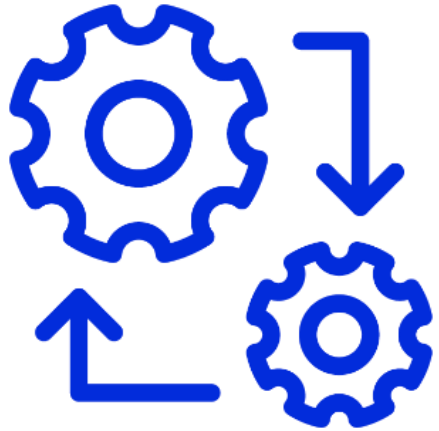
> "All measurements are subject to uncertainty and a measurement result is complete only when it is accompanied by a statement of the associated uncertainty."*

*** JCGM 100:2008 GUM 1995**

FRAMEWORK

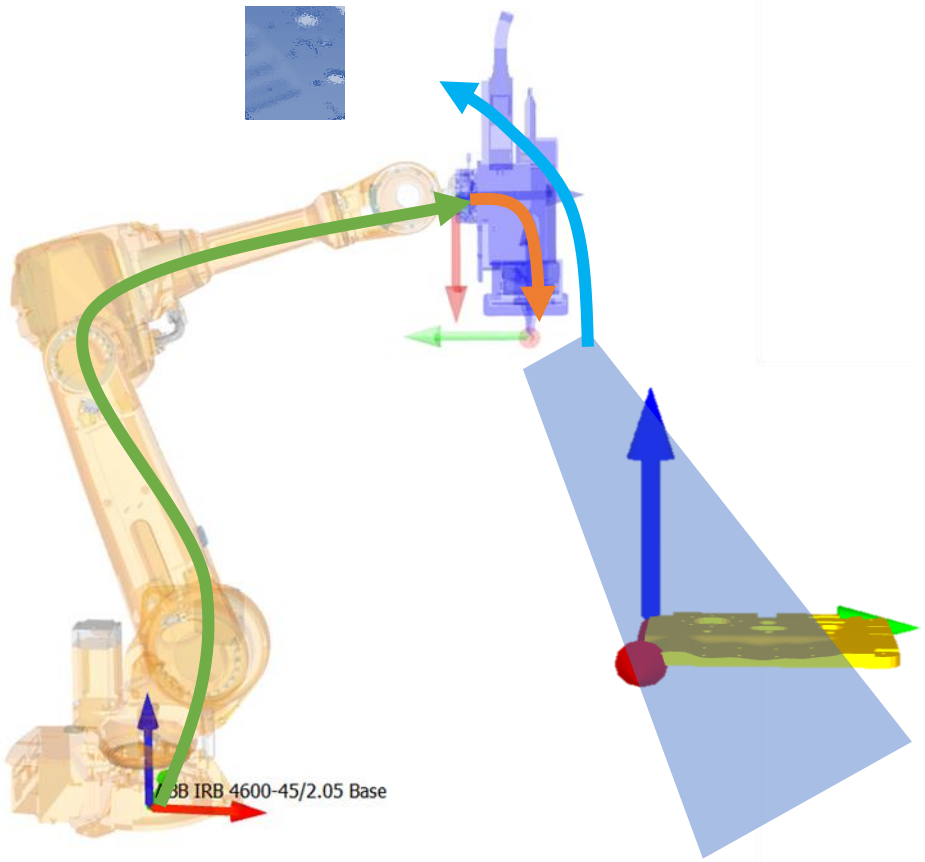


- The need to establish traceability and discuss the implications of measurement uncertainty on DTs just recently risen.
- ISO 23247:2021 : Implementation of DTs in manufacturing. Aspects for uncertainty quantification are not included.
- The European Union recently funded (ViDiT) the international research project for trustworthy virtual experiments and digital twins to advance metrological research on these topics.
- Three main questions can be highlighted:
  - How to establish traceability for a DT.
  - How to define the uncertainty and accuracy of the DTs model.
  - How to include the correction in the real word and related uncertainty in the physical measurement.



TRACEABLE DIGITAL TWIN

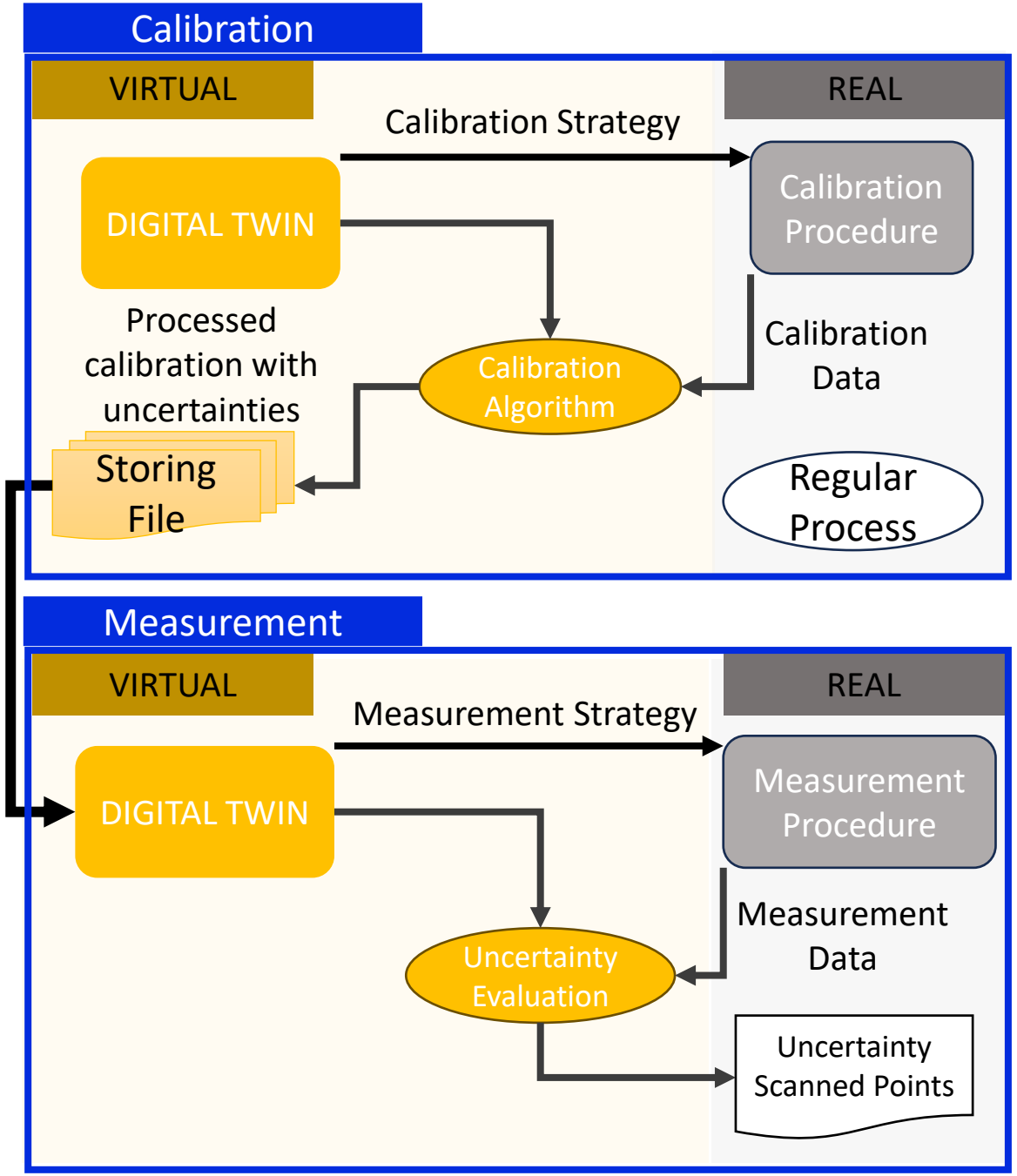
DEVELOPMENT OF THE DT



ELEMENTS OF MEASUREMENT CHAIN

1. Robot Position: the position of the robot is used for the reconstruction of the measurements.
2. Referencing of sensor to robot : the relative transformation from the robot flange to the sensor coordinate system.
3. Sensor acquisition: 2D projection line in sensor coordinate system.

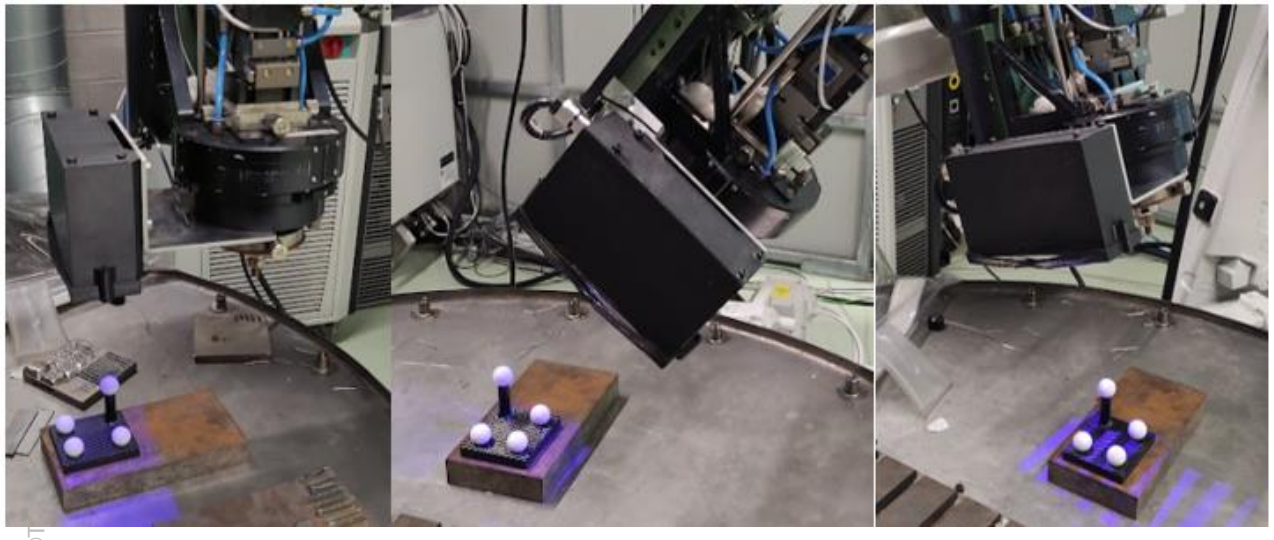
These are the main sources of uncertainty in the measurement chain.



TRACEABILITY OF THE DT

HOW DOES IT WORK?

- Communication between virtual and real world.
- Updating the DT parameter, performing regular calibrations.
- Estimation of the measurement uncertainty using the calibrated parameters.
- Implementing optimized strategies.
- Decision making.

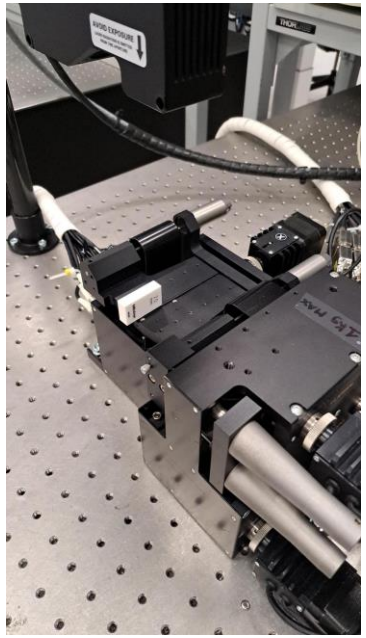
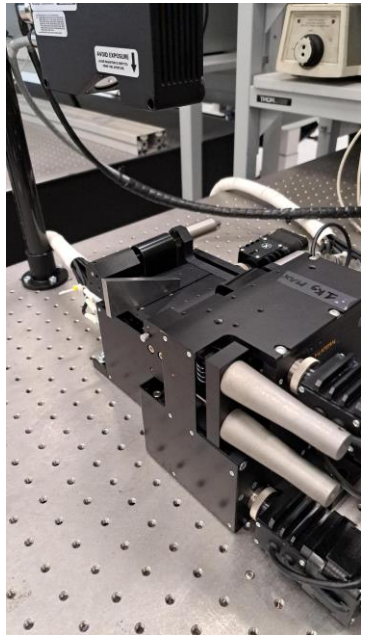
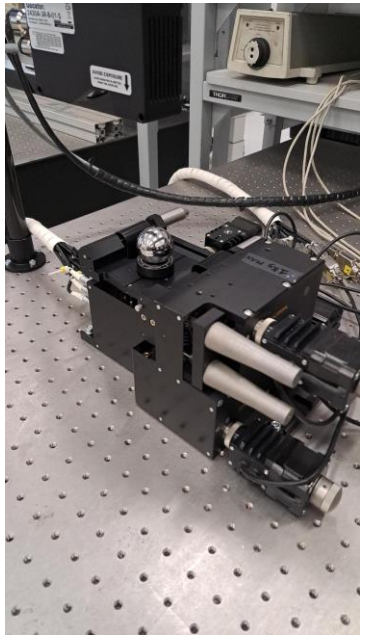
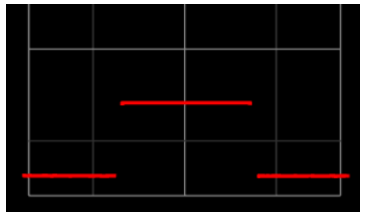
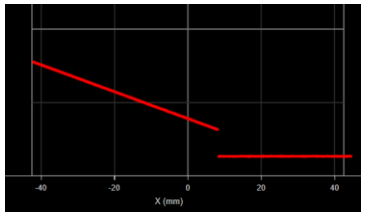


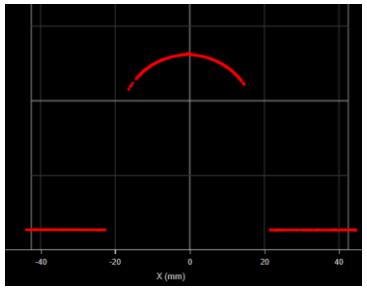
TRACEABILITY OF THE DT SENSOR:

- Robot and referencing parameters (self-calibration).
  - In process calibration.
  - Using calibrated artifact.
  - Scanning in different positions.
  - Automatic and integrated process.
  - Optimized algorithms, based on sensitivity and correlation analysis.
- Sensor parameters:
  - Offline calibration.
  - Using special artifact for vision system.

Periodic updating of the calibrated parameters.

TRACEABILITY OF THE DT SENSOR:

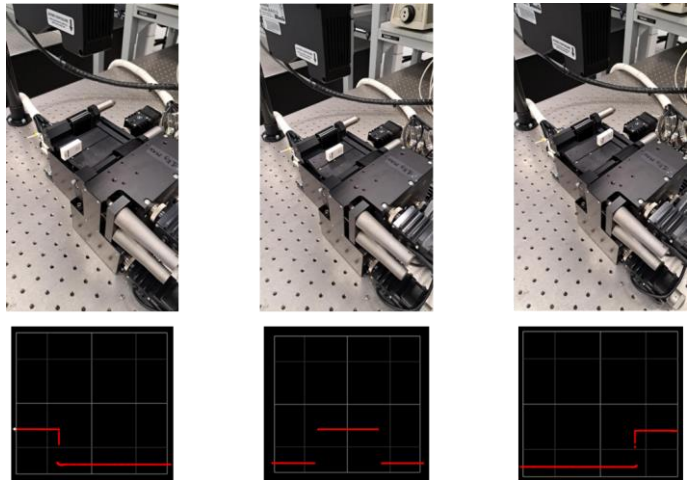






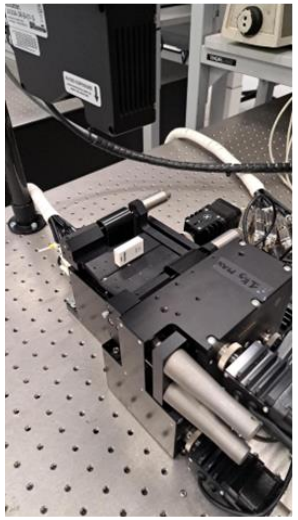


- Characterization of the sensor:
  - Shape:
    - Rectangular gauge
    - Slope gauge
    - Spheres gauge
  - Materials
  - Exposure time
  - Angle of incidence (α,β)

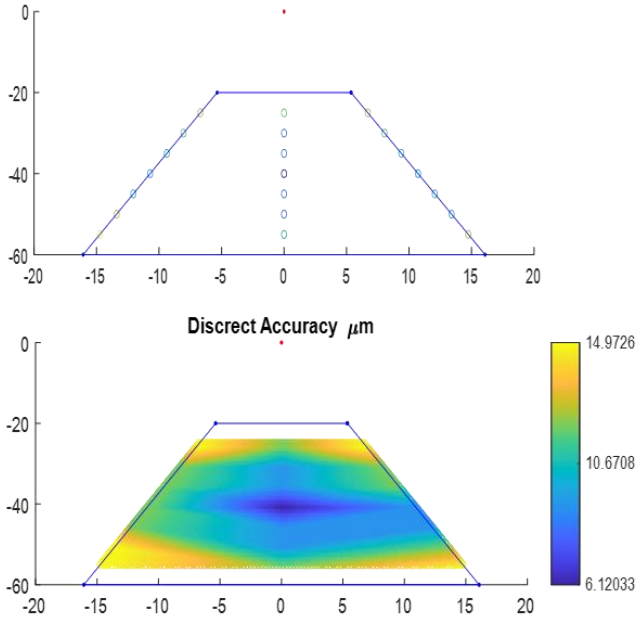
- This information is included in the virtual sensor.

TRACEABILITY OF THE DT SENSOR:



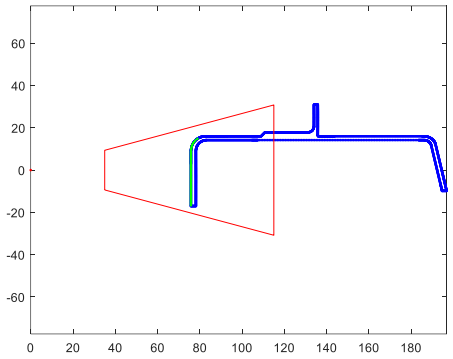


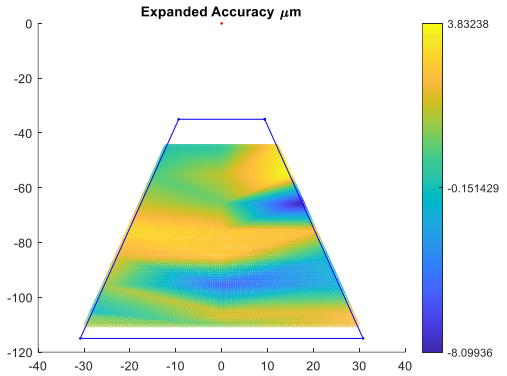
P2V

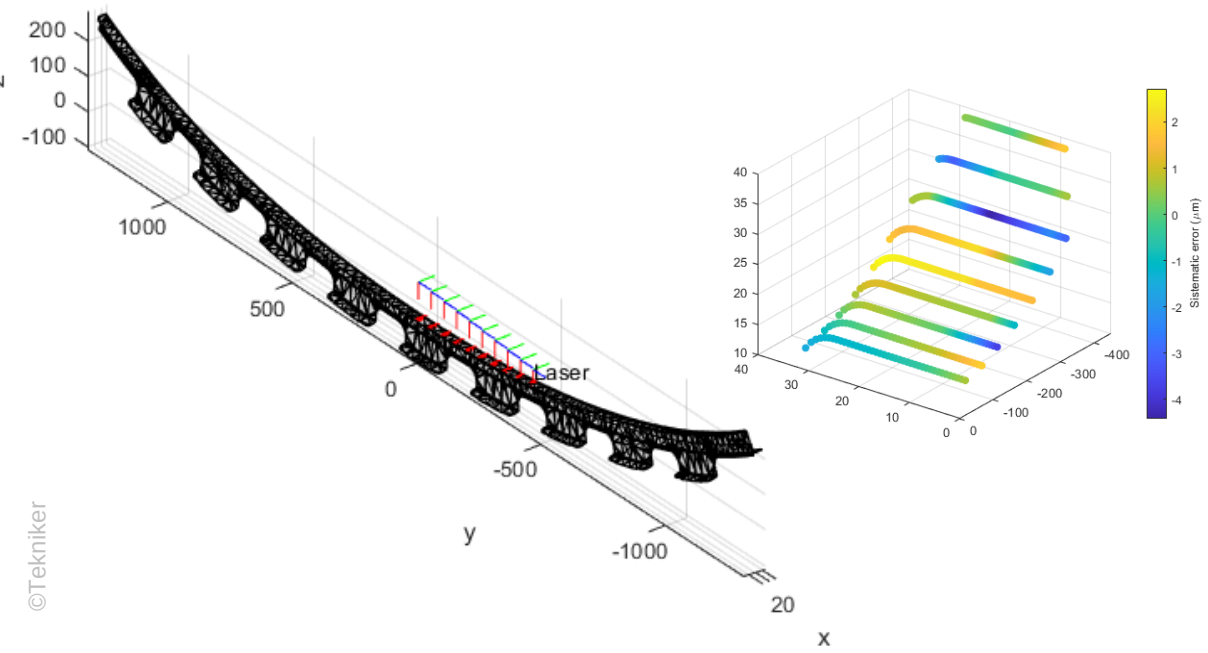


- Physical to virtual:
  - Compare with nominal values
  - Filter the signal
  - Extrapolate in the sensor range
- Output for virtual world
  - Uncertainty
  - Systematic error

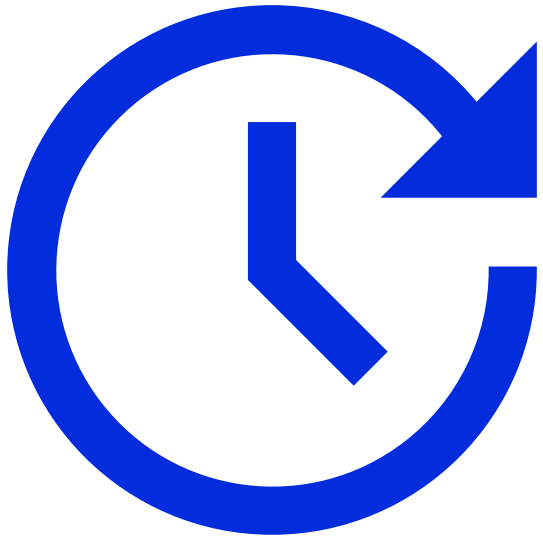
TRACEABILITY OF THE DT SIMULATE MEASUREMENT PROCESS



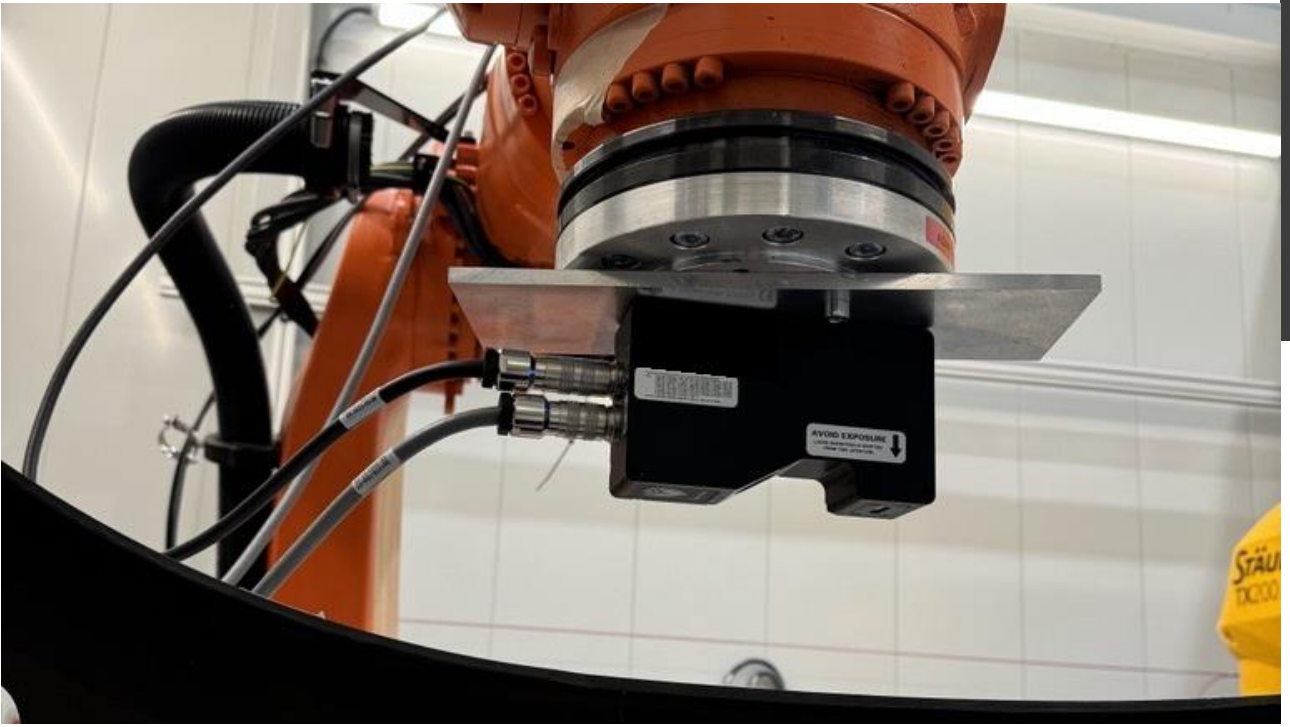


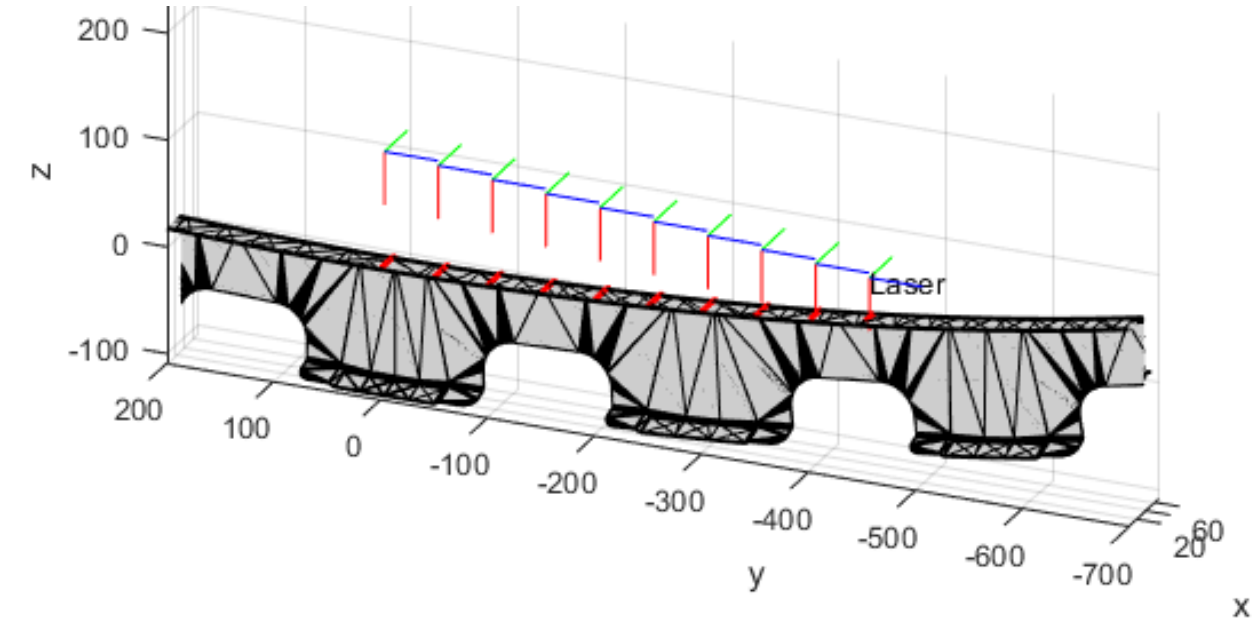


- The CAD file is loaded, and the measurement process is simulated.
- The occlusions are considered.
- The sensor accuracy and uncertainty are projected on the part surface.



FUTURE WORK





FUTURE WORK

- Validate and verify the uncertainty estimation of the DT with complex geometry calibrated artefact. Comparing with evaluation uncertainty by statistical analysis type A.
- Improving the DT by introducing different factors related to the work piece (reflectiveness, material, shape…).
- Applying surrogate models for agile DT. (Good-Enough)
- Testing the development in aeronautical industrial use case (Aernnova / AIRBUS as stakeholder).
- The close loop of the DT will help to achieve the required accuracy.

FINAL REMINDERS

- ACKNOWLEDGMENTS:

  This project is developed within the VIDIT project (Trustworthy virtual experiments and digital twins):

  "The project (22DIT01 ViDiT) has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation"

  EURAMET https://www.vidit.ptb.de/

- **WORLD METROLOGY DAY**
  - **MAY 20th**

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