Newsletter

December 2024

ViDiT (Trustworthy virtual experiments and digital twins) is a European research project within the European Partnership on Metrology programme co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States. The project has 22 participants consisting of eight National Metrology Institutes, two research centres close to industry, six universities and six companies. The project is coordinated by Physikalisch-Technische Bundesanstalt (PTB).

Why ViDiT?

Virtual experiments and digital twins are key enabling technologies to achieve and realise European strategic policies devoted to sustainability and digitalisation within the complex framework of Industry 4.0 and the European Green Deal. Virtual experiments and digital twins are both simulation models that accurately replicate physical systems and characteristics in a virtual environment. Digital twins further include dynamic updates of the virtual model according to the observed state of its real counterpart. Hence, they consist of two parts, a Physical to Virtual connection that models the considered system and a Virtual to Physical connection that implements prevention and control strategies to achieve the target accuracy in the physical system.

The use of virtual experiments and digital twins in metrological applications requires uncertainty evaluation methods, as well as reliable validation procedures, to make them fit for purpose, e.g. as substitutes or extensions, to certified measurement devices. This project will develop these methods and procedures to ensure the reliability and trustworthiness of virtual experiments and digital twins in metrology. In addition, this will enable the traceability of modern measurement systems and it will boost and strengthen the European lead in this field. To facilitate the uptake of the developed methods by National Metrology Institutes and industrial stakeholders, three good practice guides will be written, and the applicability of the methods will be demonstrated in twelve case studies covering a variety of industrial metrology applications.

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Our objectives

The overall objective of this project is to develop methods and tools that will ensure the reliability and trustworthiness of virtual experiments and digital twins in metrology in order to support digital transformation within Industry 4.0 and the European Green Deal.

The specific objectives of the project are:

1. To develop methods for evaluating the uncertainty associated with real measurements for three different applications by using the results from corresponding virtual experiments in line with the current state-of-the art for uncertainty evaluation.
2. To develop methods for uncertainty quantification for digital twins representing complex measurement processes and mechanisms for four different applications, in each case including the effect of dynamic influences on the digital model such as thermal drift or vibrations.
3. To develop approaches for the validation of virtual experiments and digital twins for all applications of objectives 1 and 2, using statistical procedures for the assessment of differences between calibrated standards and corresponding data from their virtual counterpart.
4. To demonstrate the practical applicability of the developed methods, using twelve different case studies covering all the metrological applications of objectives 1 and 2.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations and end users.

Highlights/Progress

On 13 & 14th of November 2024, the ViDiT project had a progress meeting at ENS / USPN (day 1) and LNE (day 2) and also a stakeholder workshop at LNE in Paris (Figures 1+2).

Figure 1: The ViDiT progress meeting and the stakeholder workshop was held at LNE in Paris.

LNE is the French National Metrology Institute (NMI) and LNE coordinates and manages the work of the laboratories of the French National Metrology Network (RNMF). LNE has a dual mission: to support private and public players and to work for a safer and more sustainable world.

ENS Paris-Saclay is a Grande École dedicated to research and higher education and a founding member of Paris-Saclay University. Université Sorbonne Paris Nord (USPN) is a multidisciplinary university known for its prominent mechanical engineering department. The research activities of ENS and USPN in this project are conducted in collaboration with the Automated Production Research Laboratory (LURPA), which focuses on geometrical product specification and verification, multi-sensor dimensional metrology, geometry processing, and data analytics in dimensional metrology.

The consortium discussed the work done during the first half of the project and planned for its continuation, especially for the next nine months. There were 19 persons attending the meeting on-site and 20 persons attending the meeting online.

Figure 2: Project partners at ENS.

Highlights from the project meeting

The Laboratoire Commun de Métrologie LNE-CNAM has developed an ultra-high accuracy cylindricity measuring machine called NanoCyl (Figure 3). As a primary standard, NanoCyl aims to improve the current calibration and cylindricity measurement capabilities. ISO 23247 provides a standardized reference architecture for developing and implementing digital twins. In the ViDiT project, NanocylTwin, the digital twin of NanoCyl, has been structured through the ISO 23247 architecture. The core entity, which is the layer representing the digital representation, was built to combine a data-driven approach with

a model-driven approach. This approach represents the machine's state through error sources, such as thermal drift, spindle errors, and misalignment. The implementation strategy is shown in Figure 4.

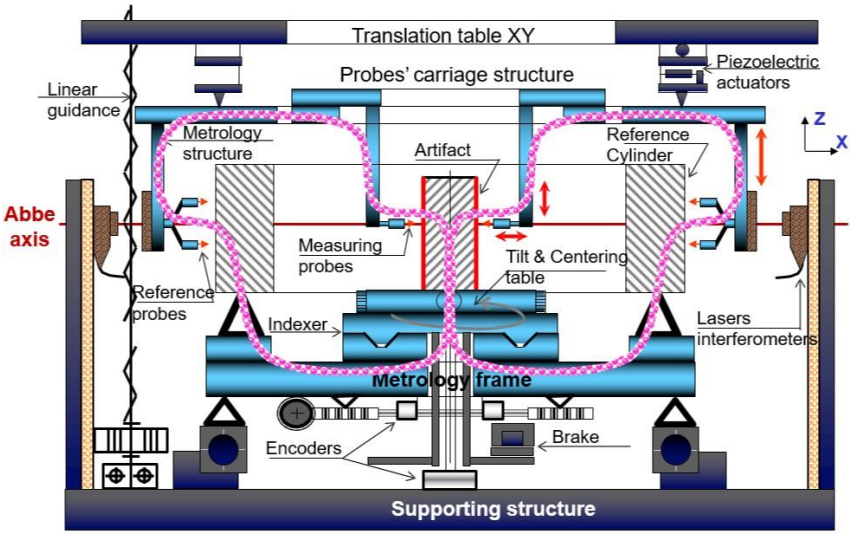

Figure 3: The NanoCyl instrument.

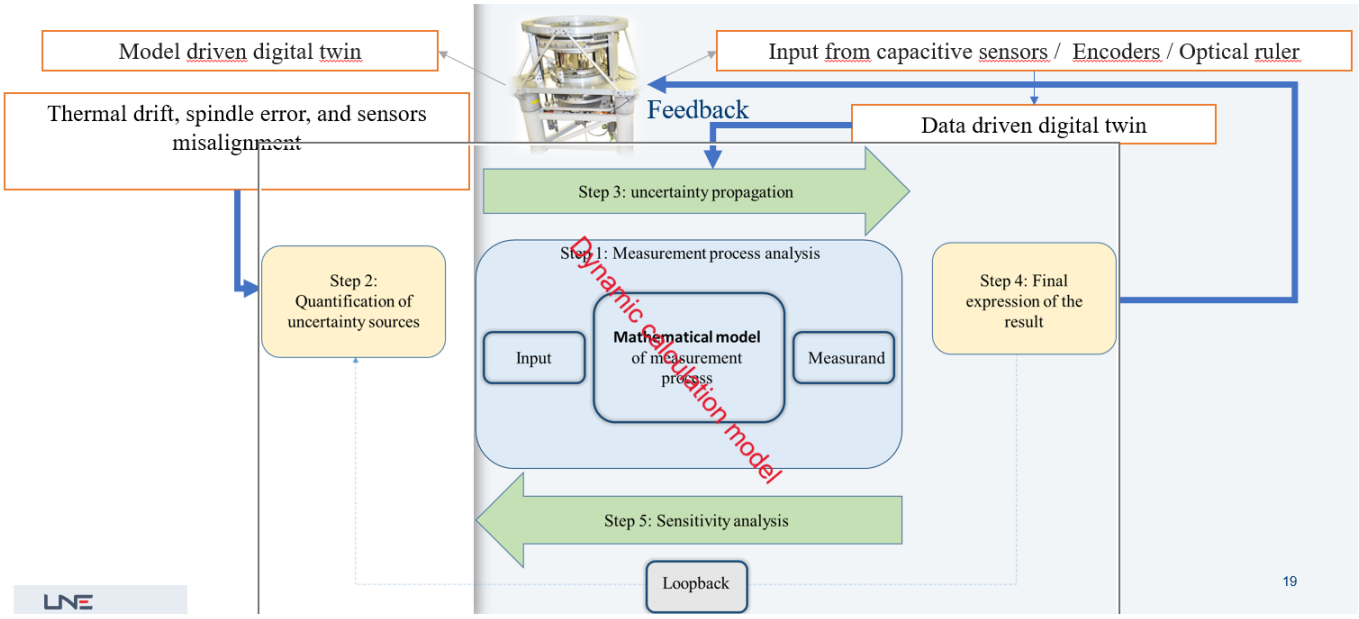

Figure 4: The implementation strategy for the developed NanocylTwin.

Stakeholder Workshop

At the stakeholder workshop, an overview of the ViDiT project was given and the following topics were presented and discussed:

- JCGM–compliant uncertainty evaluation using virtual experiments
- A metrological framework for uncertainty evaluation of digital twin
- Discussion on validation of virtual experiments and digital twins
- Overview of industrial applications in ViDiT project
- Digital twin for the estimation of insulated power cables behaviour in electrical systems
- Comparison of different uncertainty evaluation methods for virtual experiments with an application to a virtual CMM
- Measuring uncertainty of a contour measuring station
- NanocylTwin: Integrating data–driven and model–driven approaches for cylindricity measurement
- Metrology for a trustworthy digital twin of 3D robotic scanning systems
- Validation of machine vision systems and ISO 10360–13

There about 60 persons attending the stakeholder workshop, about 25 on–site and the rest attending the stakeholder workshop online. The presentations from the stakeholder workshop can be found at **the project website.**

Highlights from the Stakeholder workshop

An introduction to uncertainty evaluation of digital twins was presented by Giacomo Maculotti, Gianfranco Genta and Maurizio Galetto from Politecnico di Torino. Digital twins are simulation models that accurately replicate physical systems in a virtual environment and include dynamic updates of the virtual model according to the observed state of its real counterpart to achieve a physical control of the latter (Figure 5).

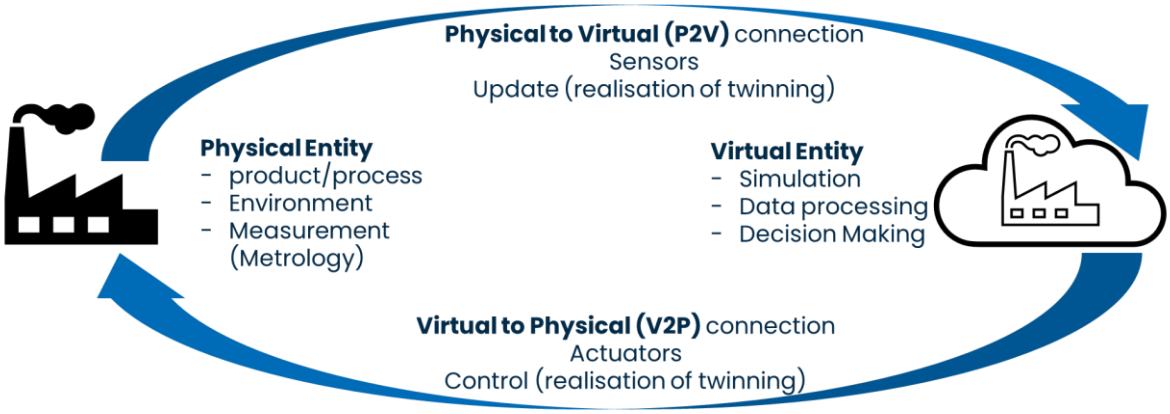

Figure 5: Concept of a digital twin.

A digital twin includes the following features:

- Fit for purpose digital representation, i.e., data element representing a set of properties of an observable manufacturing element, with synchronization between the element and its digital representation (ISO 23247–1:2021)
- Digital representation, i.e., a digital entity, representing a set of properties and/or behaviors of observable elements of a target entity, i.e., an entity providing a functional purpose in reality, with data connections that enable convergence between the physical and digital states at an appropriate rate of synchronization (ISO/IEC 30173:2023)

A full set of the slides of this presentation can be found at the project website.

Publications and conference presentations

The following peer-reviewed papers have been published in the first half of the project:

- Maculotti, G., Genta, G., & Galetto, M. (2024). An uncertainty-based quality evaluation tool for nanoindentation systems. Measurement: Journal of the International Measurement Confederation, 225(December 2023), 113974. https://doi.org/10.1016/j.measurement.2023.113974
- Marschall, M., Fortmeier, I., Stavridis, M., Hughes, F., & Elster, C. (2024). Bayesian uncertainty evaluation applied to the tilted-wave interferometer. Optics Express, 32(11), 18664. https://doi.org/10.1364/oe.524241
- Maculotti, G., Marschall, M., Kok, G., Chekh, B. A., van Dijk, M., Flores, J., ... Schmelter, S. (2024). A Shared Metrological Framework for Trustworthy Virtual Experiments and Digital Twins. Metrology, 4(3), 337–363. https://doi.org/10.3390/metrology4030021
- Marschall, M., Hughes, F., Wübbeler, G., Kok, G., Dijk, M. Van, & Elster, C. (2024). Using a Multivariate Virtual Experiment for Uncertainty Evaluation with Unknown Variance, 534–546. Metrology 2024, 4, 534–546. https://doi.org/10.3390/metrology4040033

Results from the ViDiT project have been presented at several conferences and seminars, including:

- XVth International Scientific Conference "Coordinate Measuring Technique" in April 2024 in Poland, where Adam Gąska (PK) presented a poster entitled “Trustworthy virtual experiments and digital twins as a base for modern quality control in digital production”.
- ENBIS Spring Meeting 2024 in May in Germany, where Gertjan Kok, Marcel van Dijk (VSL) and Manuel Marschall (PTB) gave a presentation “On the trustworthiness of simulation based uncertainty evaluations for industrial measurement instruments like CMMs”.
- Seminar of precision engineering (MIKO 2024) in June 2024 in Vantaa, Finland, where Linus Teir and Björn Hemming (VTT) gave a presentation on “Inspection of 3D measurement instruments” (in finnish).
- IEEE International Conference on High Voltage Engineering and Application (ICHVE 2024) in August in Germany, where Fernando Álvarez (FFII) presented a poster about the “Development of a digital twin for the estimation of insulated cable systems behavior over time”.
- IMEKO 2024 World Congress in August in Germany, where results of the ViDiT project have been presented in several talks and a poster:
  - Finn Hughes (PTB) gave a presentation about “JCGM 101-compliant uncertainty evaluation using virtual experiments”.
  - Marcel van Dijk (VSL) talked about “Comparison of uncertainty evaluation methods for virtual experiments with an application to a virtual CMM”.
  - Matias Alberto Aguirre (INTI) provided a poster on “Virtual Experiment of Temperature Rise Test in High-Voltage Switchgear” (presented by Diego Nahuel Coppa).
  - Sonja Schmelter (PTB) gave a talk on “Metrology for virtual measuring instruments” within the “CIPM/IMEKO Workshop on Metrological Traceability”.
- VII IEEE ARGENCON in September in Argentina, where Matias Alberto Aguirre (INTI) et al. gave a presentation entitled “Virtualization of Standard Test for Implementation on Virtual Experiment and Digital Twins”.

- 3D Metrology Conference (3DMC 2024) in September in the United Kingdom, where B. Ahmed Chekh (Tekniker) and Pablo Puerto (Ideko) talked about “Metrology for trustworthy digital twin of a 3D robotic scanning system”.
- The 20th International Conference on Precision Engineering (ICPE 2024) in October in Japan, where two presentations were given:
  - Enrico Simonetto (UNIPD) et al. gave a presentation entitled “Integrated metrology in manufacturing: connecting digital twins and applications in metal forming”.
  - Giacomo Maculotti (POLITO) et al. talked about “Towards Nanoindentation Metrological Digital Twin: traceable automated procedure for out-of-control measurements identification”.

Previous conference presentations of ViDiT are listed in the previous newsletter which can be found *at the project website.*

Some facts:

Project start date and duration:	May 2023, 36 months	
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Internal Funded Partners: 1. PTB, Germany 2. FFII, Spain 3. GUM, Poland 4. LNE, France 5. VSL, Netherlands 6. VTT, Finland	External Funded Partners: 1. ENS Paris-Saclay, France 2. IDEKO, Spain 3. INTI, Argentina 4. PK, Poland 5. POLITO, Italy 6. TEKNIKER, Spain 7. UNIPD, Italy 8. UPM, Spain 9. USPN, France	Unfunded Partners: 1. DUI, Netherlands 2. FLEXIM, Germany 3. GEOMNIA, France 4. KROHNE, Germany 5. Mahr, Germany 6. SICK, Germany 7. TUBITAK, Türkiye

Participants:

Funding:

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