ITEA 4

Project Results

ASIMOV

Combining digital twins and AI for machine optimisation

The ITEA project ASIMOV (AI training using Simulated Instruments for Machine Optimisation and Verification) has developed an innovative approach combining artificial intelligence (AI) and digital twins (DTs) to enable the optimisation of complex systems.

High-tech systems are becoming increasingly complex, particularly when interacting with uncertain environments. This can create a tension between the need for high uptimes and ease of use, as suppliers must deliver optimal quality without difficult, time-consuming optimisation tasks that require skilled staff. How to build complex high-tech systems that select their optimal settings autonomously within a minimal timeframe and with minimal external expertise?

ASIMOV's proposed solution is AI-based software that autonomously performs system optimisation tasks during manufacturing, installation and system usage. This is more an approach than a specific technology: the creation of DTs, upon which AI is trained and subsequently applied to real systems, is a generic concept that can be utilised with many use-cases and technologies. ASIMOV aimed to lay the foundation for this and therefore developed proofs of concept in two industrial system domains for which optimisation is crucial to system performance: electron microscopes (EM) and test case generation for automated driving of unmanned utility vehicles (UUV).

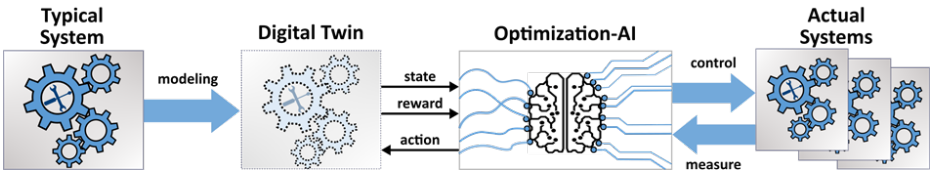
Technology applied

Across the use-cases, ASIMOV targeted four main innovation opportunities: (1) methodologies to effectively create DTs to simulate typical, realistic system behaviour; (2) a novel AI optimisation algorithm to rapidly uncover optimal system settings; (3) verification of the DTs to train the AI; and (4) systematic integration and deployment of the trained AI to perform tuning and calibration tasks on real machines during manufacturing, installation and operational use. The latter takes place through direct interaction with the system and through the use of a DT of the actual system under configuration in order to evaluate system settings. For system level realisation, ASIMOV also developed a reference architecture on how to best put together the different components needed for this interplay between DTs and AI.

The adaptability of this approach has been demonstrated through its application to two very different fields. In the UUV use-case, a flexible architecture was developed for vehicle-in-the-loop (the physical twin), automotive offroad and maritime. This allowed for automated generation of critical test cases by varying the 3D environment, resulting in a fully automated system that reduces time on the testbed/proving ground. For the EM use-case, optical aberrations must be minimised to enable optimal resolution and quantitative analysis. By creating DTs of the relevant parts of a microscope and using these to train AI, ASIMOV has arrived at a way to correct low-order aberrations effectively.

Making the difference

ASIMOV has now achieved its goal of producing two use-cases in which AI works with DTs to train itself, demonstrating both the feasibility and flexibility of this approach. In the EM market, more automation will result in higher productivity and DTs will provide an enhanced understanding of system behaviour. For end-users, the corresponding faster, easier alignment of microscopes will translate into a reduction of expertise needed, which reduces the need for microscope operators at customer sites. For UUV, uptake of ASIMOV's outcomes can lead to market growth and expansion



The ASIMOV principle. By modeling relevant aspects of a CPS into a physical realistic digital twin, an Optimisation-AI can be trained to control the CPS without need of training time on the actual CPS. Once trained, the AI can operate a range of CPS's and keep them in optimised state.

to include public transport, off-road driving and maritime transport, as well as the increased quality and reliability required for higher-level autonomy while still improving cost efficiency. Given the generic nature of ASIMOV, similar benefits would be felt in other domains to which DT-trained AI can be applied.

In the meantime, ASIMOV has already brought a number of benefits to its partners. For OEMs, the primary result is a competitive advantage over companies that have yet to exploit AI. For AVL, for instance, the UUV use-case has given valuable insights into 3D environment variation as a future tool for scenario generation, providing them with more flexibility in the identification of critical test cases for the testbed. In the EM use-case, meanwhile, Thermo Fisher has a potential new means of aligning and operating their microscopes. This is difficult to achieve in any other way, either by humans or regular automation. As for ASIMOV's five SMEs, the project has further developed their knowledge and competencies in both DTs and AI, which they can apply to services or products in other settings. For example, CQM is now expanding the approach to the completely different domain of supply chain and logistics.

For RTOs and academia, the project has not only opened up new research avenues but has already resulted in two completed master's, one completed PhD, two ongoing master's and 1 completed bachelor's thesis projects. Additional outputs of ASIMOV include the Cookbook – a consortium effort to summarise the project's expertise and experience so that others can avoid the same mistakes or can replicate the successful strategies – and an open-source concept demonstrator, which can assist in ongoing outreach activities beyond the consortium. Coupled with the continued internal development of the technologies per partner (possibly in modified formats), the groundwork has been laid to ensure that ASIMOV's concepts and ideas are here to stay.

Major project outcomes

Dissemination

- 16 publications (e.g. Bits & Chips, Brainport Eindhoven, OFFIS in-house public magazine article "Datawork") and peer-reviewed publications.
- 21 presentations at conferences/fairs (e.g. CDC 2023 AND 2024, ECC 2024, ACC 2023, Autonomous Vehicles Europe 2023).
- 1 bachelor's, 2 completed MSc, 1 Phd completed, 2 ongoing MSc thesis.
- The CookBook: provides a starting point for system architects and system engineers that are faced with the question: how to build complex high-tech CPSs that select their optimal settings autonomously within minimal time and with minimal external expertise?
- An Open Source concept demonstrator: explores the impact of digital twinning modelling decisions and the systems engineering challenges imposed by RL.

Exploitation (so far)

- Consideration on parameter identifications for Digital Twin.
- Architecture of optimised Digital Twin.
- Architecture for Digital Twin based AI training.
- Methods and tools for training AI with Digital Twin.

Patents

- 1 patent application filed.

ITEA is the Eureka RD&I Cluster on software innovation, enabling a large international community of large industry, SMEs, start-ups, academia and customer organisations, to collaborate in funded projects that turn innovative ideas into new businesses, jobs, economic growth and benefits for society. ITEA is part of the Eureka Clusters Programme (ECP).

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ASIMOV

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Partners

Germany

- AVL Deutschland GmbH
- Deutsches Zentrum für Luft- und Raumfahrt (DLR)
- LiangDao GmbH
- NorCom Information Technology GmbH
- OFFIS
- RA Consulting GmbH
- TrianGraphics GmbH

Netherlands

- CQM
- Eindhoven University of Technology
- Thermo Fisher Scientific
- TNO

Project start

June 2021

Project end

May 2024

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