ITEA 4

Project Results

AIToC

Entering the AI era of manufacturing engineering

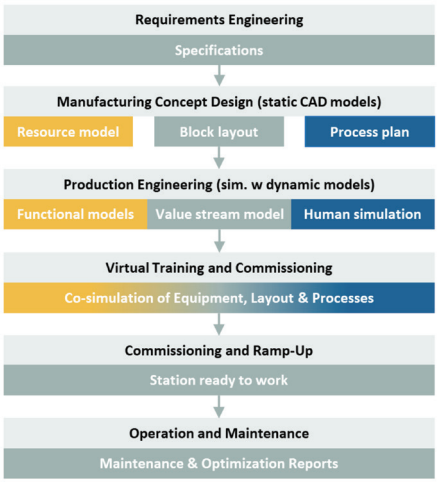
Through the use of artificial intelligence (AI) methods, the ITEA project AIToC (Artificial Intelligence supported Tool Chain in Manufacturing Engineering) has developed an integrated toolchain to support manufacturing engineering with process planning, data-driven digital twin creation, and layout optimisation.

Manufacturing engineering relies heavily on software tools for planning, simulation and automation, yet even small sets of product variants are difficult to create due to the many combinations that impact the production systems. With the need to adapt tools to individual companies, the deficiencies in current product/production definitions and requirements, and the manual efforts of creating digital models and representations, engineers face enormous volumes of work when attempting to create the required models.

To reduce this burden, AIToC envisions digitalised, automated and AI-supported manufacturing engineering in all phases, thereby enabling model-based emulation, simulation, visualisation and requirements. To achieve this, the project has improved existing tools or developed new tools for the definition and management of requirements and the generation of process plans, equipment models and layout. This supports decision-making from a very early stage, as well as general planning and optimisation, and is expected to boost industry with tool interoperability, simulation flexibility and improved manufacturing engineering capabilities, among other benefits.

Technology applied

The technological core of AIToC is the use of AI and/or data-driven tools to improve engineering work, which can be divided into three themes. The first concerns AI-based assistance in the generation of process plans and instructions, for which a major achievement has been proving that modern AI tools can support the formalisation and generation of requirements. On the basis of a formalised product definition, manufacturing processes can be identified and selected with the support of semantics and ontologies that enable computer-supported/automated process plan generation. Such plans can be used in tangent with flexible, modular systems for information provision in manual processes in order to guide operators. With the introduction of AI-based methods, context-aware operator assistance becomes possible.



3 Themes

Theme 1: AI-based assistance in generation of process plans and instructions

Theme 2: AI-generated models and support for co-simulation of humans and machines

Theme 3: Systematic layout generation and AI-based logistics planning

The second theme focuses on AI-generated models and support for co-simulation of humans and machines, examining the possibility to create behavioural models of several systems, such as production components and equipment. With real measurement data from component manufacturers, AIToC demonstrated feasible data-driven methods to generate this. Another notable success in this theme is the creation of the open-source BRICK format for reusable, extendable simulation models, which can be used to describe full systems such as factories.

Finally, the third theme deals with systematic layout generation and AI-based logistics planning. The key highlight in this area is a vision-based update to digital twins in logistics operations that utilises optical sensors (such as ceiling-mounted cameras) to track the dynamic environment of a factory setting. In particular, this focuses on how such digital representation can enhance the planning and operation of mobile robots in industrial spaces.

Making the difference

Innovation is a long journey and AIToC has taken an initial step into AI and data-driven manufacturing engineering, through which companies will be able to speed up changes in product development and better deal with variability. As a result, their operations can become more efficient in terms of

costs and lead times while ensuring or improving quality. In turn, this will afford manufacturing companies with improved (international) competitiveness at a global level while reducing waste and thereby helping to meet ongoing sustainability efforts. Through the tools provided by AIToC, companies can proactively anticipate the next big opportunity in manufacturing engineering – a key element of the digital transformation of how business is carried out.

In total, AIToC has led to over 50 exploitable results, each of which will be developed further through some combination of commercialisation, business integration, open-source release and academic dissemination. The vision-based update of digital twins in logistics operations, for instance, has received an industrial evaluation in full production at Volvo's plant in order to help them manage a heterogenous environment of human operators and forklifts; this innovation has also contributed to three PhD theses on various aspects of its technology. AI-based assistance in the generation of process plans and instructions, meanwhile, has led to a toolchain of eight modules that can be combined as necessary, including for context definition, modelling and reasoning, information generation and visualisation, and/or sensor data interpretation.

As open-source standards have been missing in this field for a long time, another crucial result of AIToC is the democratisation of digital twins through the BRICK format. By making this and other open-source elements available, the project allows companies of all sizes and financial capacities to improve their manufacturing engineering efficiency. This also promotes the widespread deployment of the technologies and tools over the longer term. At the same time, AIToC has led directly into the ITEA project ARTWORK, which will build on these results to develop a solution for digital twins of factory workers and equipment, smart instruction generation and a worker feedback system, thereby propagating a lasting impact for AIToC beyond its immediate exploitation.

Major project outcomes

Dissemination

- Several final result videos at https://aitoc.eu/
- 20+ publications, including several PhD, master and bachelor thesis
- 20+ conference / event presentations

Exploitation (so far)

More than 50 exploitable results. Many of these results automate the engineering preparation work when developing and updating the manufacturing system. For example:

- **An AI-powered operator instruction and reasoner toolchain**, that can generate operator instructions automatically based on AI-based reasoning, CAD-features and rules.
- **A new open-source physics modelling format called BRICK**, which supports rapid modeling and analysis as well as accurate training of reinforcement learning algorithms.
- **A new AI platform to generate new functional mock-up units which can include neural network models.** This platform enables rapid creation of dynamic models based on sampled data which enables early virtual validation and commissioning of control systems.
- **A layout optimisation tool,** that will automatically generate an optimal layout of a manual assembly station which minimises walking distance and improves ergonomics.
- **A new transport solution using fixed cameras in the ceiling for controlling automated transport robots without expensive onboard sensors.** This drastically reduces the required investment and speeds up the installation and commissioning of new automated transport systems.

Standardisation

- Contribution to open-source standards: many of the project results have been created in the form of open-source code.
- Proposal to include MMUs (Manikin Mockup Units) in the FMI-standard.

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Partners

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- Lappeenranta University of Technology
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- Process Genius Oy
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- TactoTek

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- Univrses AB
- Volvo

Türkiye

- ARD GROUP
- Eryaz Software
- Ford Otosan
- TOFAS A.S.
- UNIT Information Technologies R&D Ltd.

Project start - project end

October 2020 - February 2024

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Project website

https://itea4.org/project/aitoc.html

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