AI-augmented Model-Based Capabilities in the AIDOaRt Project: Continuous Development of Cyber-Physical Systems

Article *in* ACM SIGAda Ada Letters · April 2023

DOI: 10.1145/3591335.3591349

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Abstract

The paper presents the AIDOaRT project, a 3 years long H2020-ECSEL European project involving 32 organizations, grouped in clusters from 7 different countries, focusing on AI-augmented automation supporting modeling, coding, testing, monitoring, and continuous development in Cyber-Physical Systems (CPS) and the tools covering the model-based capabilities requirements in the project.

Keywords: Model-Based Engineering, Cyber-Physical Systems, Development Operations, Artificial Intelligence .

1 Introduction

The AIDOaRt[1] project aims at supporting systems engineering and continuous delivery activities, namely requirements engineering, modeling, coding, testing, deployment, and monitoring, with AI-augmented, automated Model-Based Engineering (MBE)[2] and Development Operations (DevOps). To achieve this goal, AIDOaRt proposes a model-based framework architecture (cf. Figure 1) that specifies proper methods and tools to enable design and run-time data collection, ingestion, and analysis to provide tailored and efficient AI/ML solutions that will be integrated and evaluated on concrete industrial case studies involving various Cyber-Physical Systems (CPS). The objective of the project, as shown in Figure 1, is to provide a model-based framework to support the CPS development process by introducing AI-augmented automation. Enhancing the DevOps toolchain by employing AI and Machine Learning (ML) techniques in multiple aspects of the system development process (such as modeling, coding, testing, and monitoring), supporting the monitoring of runtime data (such as logs, events, and metrics), software data, and traceability (Observe), analyzing both historical and real-time data (Analyze) and the automation of functionality (Automate).

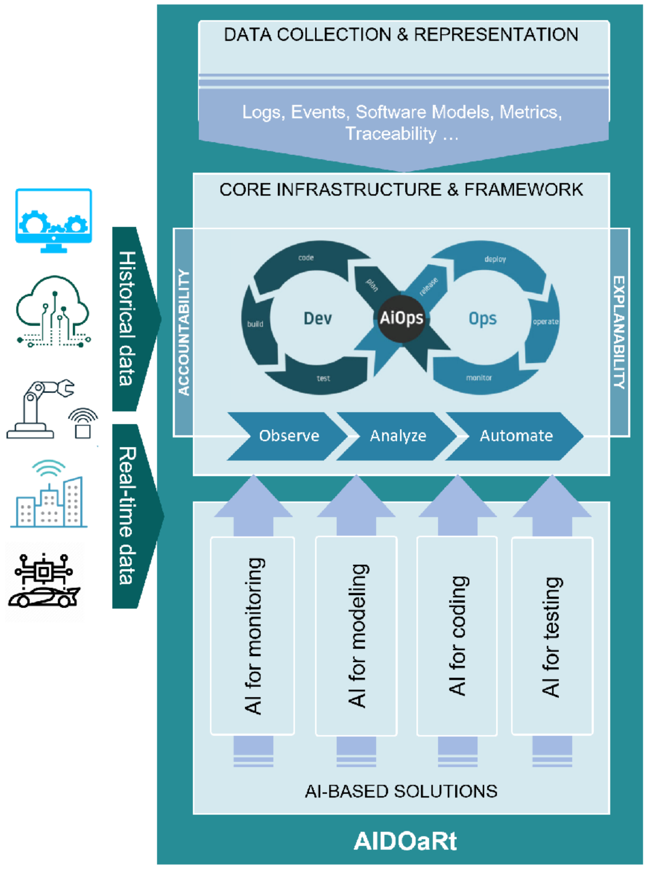

Figure 1 Overview of the AIDOaRt approach

2 The AIDOaRT Project

The project started up on 1st April 2021 and involves 32 industrial and academic partners from different European countries [1]. The AIDOaRt project consortium consists of three distinctly different categories of organizations with respect to interests and plans. The organization types are Research Partners, Industrial Use Case Partners and Technology Provider Partners. The industrial use case partners provide industrial case studies for the project. Each case study comes with a set of requirements and a set of existing technologies and tools which are offered to the other two types of partners as a set of baseline technologies. Both the technology providers and the research partners develop new technologies and tools to satisfy the requirements specified by the industrial use case

[1] https://www.aidoart.eu/

[2] In this paper, we interchangeably use both Model-Based Engineering (MBE) and Model-Driven Engineering (MDE), although we are aware that MDE recalls a higher automation degree (cf. https://modeling-languages.com/clarifying-concepts-mbe-vs-mde-vs-mdd-vs-mda/)

partners. They use the baseline technologies offered by the industrial use case partners and perform various research and development tasks to develop new capabilities and technologies, which act as potential exploitation assets. Finally, the new capabilities and technologies developed by the technology providers and research partners are evaluated and adopted by the industrial use case providers. In this way, the industrial use case providers benefit from the newly developed AIDOaRt technologies and tools. Moreover, the technology providers and research partners benefit by working on important, industry-relevant research and development problems and use case requirements. In particular Industrial Use case partners provide 15 industrial case studies capturing CPS of varying complexity levels and in different application domains, ranging from automotive to software and communication systems. AIDOaRt Research and industrial partners propose a set of 50+ candidate solutions that are potentially relevant to either directly tackle the case study requirements, or generally fit within the framework of AIDOaRt, to fulfill typical data-centric, AI-augmented, or model-based engineering requirements. These solutions also vary in their offered services (113), the consumed or produced input/output data, and the technical constraints such as data requirements, supported platforms and deployment procedures.

3 Project Requirements

The nature of our AIDOaRt project, in terms of number of partners and variety in requirements and proposed solutions, requires the adoption of an agile methodology to gradually define the architecture and to incrementally collect, refine and clarify the requirements, and map them to candidate solutions. Industrial use case partners have identified in these case studies a quite varied list of 128 functional and data requirements that are satisfied by the project available tools. The requirements largely differ in terms of abstraction levels, broadness, and coverage and they cover the five key SE/DevOps activities (Requirements Engineering, Modeling, Coding, Testing and Monitoring) and cover different desired capabilities. Figure 2 shows the AIDOaRt Core Tool Set component and use case requirements related to the Model-based capabilities. This component supports the loading, navigation, querying, transformation, tracing/federation and then the saving of the required models and metamodels For example, Volvo requires the “development of standard data classification, reusable definition, representation, usage (VCE_R07)” as well as to “customize standards based modeling frameworks (e.g. UAF, SysML, UML) and metamodels to develop system, software, data architecture models (VCE_R05)”. The adopted agile methodology [3] allows us to integrate newly reported updates on requirements and solutions descriptions from all partners in a flexible, simple and traceable fashion.

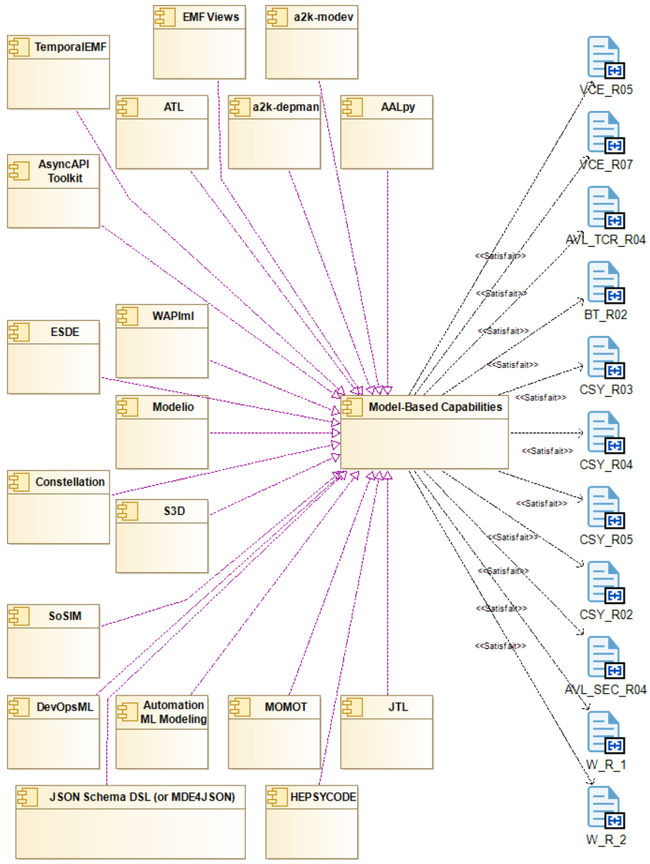

Figure 2 Model-Based Capabilities Traceability Diagram

3 Some Project Tools

This section provides the description of some of the tools developed by IMTA, SOFTEAM, JKU, MDU and UNIVAQ that will be extended and used in the context of the overall AIDOaRt approach to respond to the model-based capabilities requirements.

3.1 IMT Atlantique (IMTA) Tools

EMF Views[3] is an Eclipse-based solution that brings the concept of database views to the modeling world. It allows creating model views that focus on only one part of a model, or views that combine several models together (and that potentially conform to different metamodels). Model views can be navigated and queried as regular models, and they can be used as inputs to model transformations (notably transformations specified in ATL).

ATL (ATL Transformation Language)[4] is an Eclipse-based model-to-model transformation language and toolkit. In the field of Model-Driven Engineering (MDE), ATL provides ways to produce a set of target models from a set of source models. Complementary to EMF Views and ATL, *NeoEMF*[5] is a model persistence solution designed to store models in several kinds of NoSQL datastores. It is fully compatible with Eclipse/EMF, thus making it easy to integrate into (EMF-based) modeling applications.

3 https://www.atlanmod.org/emfviews/
4 https://www.eclipse.org/atl/
5 https://neoemf.atlanmod.org/

In the context of AIDOaRt, the plan is to reuse and extend (possibly significantly) EMF Views in order to support the development of various news features of the tool as well as their application within different AIDOaRt use cases or scenarios. Thus, we already plan new contributions to EMF Views itself (e.g. in terms of extensions to the tool, realized as Eclipse plugins). Concerning ATL, the plan is to reuse it as is in order to support the development of various features for other tools / components / use cases. Thus, we do not plan any new contribution to ATL itself. No new contributions are also currently planned concerning NeoEMF. In general, all the refinements and extensions developed in the context of AIDOaRt will be made completely available as open source Eclipse plugins under the terms of the Eclipse Public License v2.0 (EPL 2.0). They may also be made available under the following open source Secondary Licenses when the conditions for such availability set forth in the Eclipse Public License, v. 2.0 are satisfied: GNU General Public License, version 3.

3.2 Softeam (SOFT) Tools

Modelio[6] is an open-source modeling environment supporting industry standards like UML and BPMN. Modelio proposes various extension modules and can be used as a platform for building new Model-Driven Engineering (MDE) features such as model analysis through querying, code generation and reverse engineering of Java and C++.

Modelio Constellation, commercialized under the name "Modelio SaaS"[7], by Softeam, Docaposte, is a cloud-based requirements, systems modeling and project governance tool that offers simplified, concurrent and collaborative access for large teams to the models in the Modelio environment. Modelio SaaS is used to model the case study requirements, solutions descriptions and implementation roadmaps, and the architecture specifications. A shared and distributed repository holds and synchronizes the various model fragments and artifacts. This repository represents a single source of truth for all the partners as well as a “live” model that is continuously updated by each partner throughout the whole project lifetime. Fragments and particular views of these model artifacts are automatically exported into human-readable documents and serve as the basis of the various project deliverables.

In AIDOaRt, Modelio will be enriched with extensions to facilitate System Architects efforts while defining requirements and system modeling, adding in particular non-functional properties modeling as well as advanced analysis techniques based on AI for inference working on standards like UML and SysML.

3.3 Johannes Kepler University Linz (JKU)

AutomationML[8] (AML) is a modeling language based on CAEX the Computer Aided Engineering Exchange (CAEX) IEC standard[9]. CAEX is a neutral data format that allows storage of hierarchical object information. AutomationML was originally devised to support the engineering of cyber physical production systems (CPPS) by combining physical topology with 3D geometrical kinematics, and PLC software logic. CAEX and AML standards are developed in the XSD/XML technical space. JKU, as a member of the AML consortium, together with 54 other industrial and academic partners and, during the years, is developing MDE framework around AML and CAEX, in order to make them fully integrable with other standards (e.g., SysML) and, more in general, to bridge it with the Eclipse Modeling Framework (EMF) tand related technologies. In AIDOaRt, we plan to adopt a *AML modeling workbench*[10], to satisfy modeling requirements (e.g., VCE05 and VCE07 stated in the previous section), promoting the adoption of AML/CAEX standards in AIDOaRt model-driven engineering processes.

MOMoT is a search-based model transformation tool that allows the optimization of in-place model transformation orchestration to solve engineering problems. Based on Eclipse EMF, in MOMOT the problem and solution domains are defined by the same Ecore-based metamodel. As a consequence both concrete problem and solution(s) are conforming *problem and solution instance models*. MOMOT relies on Henshin, a graph-based model transformation framework to generate solution instance models that optimize given *objectives* and while satisfying given *constraints*, specified in Java or OCL. Currently, MOMOT adopts MOEA[11] as a base meta-heuristic search framework. Currently, we are working on extending MOMOT with reinforcement learning techniques.

MDE4JSON (a.k.a. *JsonSchemaDSL*) is one of the first results of the AIDOaRt project [4]. The approach allows the integration of arbitrary JSON-based artifacts in a fully fledged MDE process. reusing the native JSON concrete syntax/textual notation and generating Xtext-based editors. In AIDOaRt, it can be used both by UC and solution providers that manipulate JSON documents as shown for Keptn in continuous delivery scenarios [4].

DevOpsML is a EMF-based *conceptual framework* in its inception phase, developed in the context of the Lowcomote project[12] for modeling and integrating models representing *DevOps process(es)* and *platform(s)*. In AIDOaRt, DevOpsML can be used to create a simplified architectural model for AIDOaRt solutions or the overall framework itself.

3.4 Mälardalen University (MDU) Tools

MDU has collaborated with several companies with the common objective of introducing more formal ways of modeling, to move from descriptive to prescriptive uses of models (e.g. to enable continuous MBD). In particular, a tool has been developed to enable the bidirectional mapping from descriptive to prescriptive architecture

[6] www.modelio.org
[7] https://www.modeliosoft.com/fr/solutions/modelio-saas.html
[8] www.automationml.org
[9] https://en.wikipedia.org/wiki/CAEX
[10] https://github.com/amlModeling/caex-workbench/
[11] http://www.moeaframework.org/
[12] www.lowcomote.eu

modeling support by considering Draw.IO diagrams and a domain-specific language (DSL) defined through an xText grammar. In turn, the DSL enables analysis about the correctness/completeness of the architectural specifications.

The plan for AIDOaRt is to use the realized mapping and the lessons learned from that experience to introduce prescriptive modeling in other use cases. Indeed, we consider the existence of these forms of modeling as a precondition for enabling the AI-augmented interplay of DevOps and MDE.

3.5 University of L'Aquila (UNIVAQ) Tools

JTL[13] (Janus Transformation Language) is an EMF/Eclipse based model-driven framework specifically tailored to support model synchronization and traceability. In particular, JTL allows to specify and execute model transformations in both forward and backward direction. It is specifically tailored to support non-bijective transformation (non-determinism). Also, JTL allows model synchronization and change propagation by means of bidirectional model transformation. Finally, JTL can automatically generate traceability relations between different models (e.g., runtime and design models) by exploiting bidirectional model transformations and automated reasoning techniques (answer set programming). Such traceability models can be used as inputs to any other EMF-based modeling and analysis tool (e.g., e.g. for model transformations, code generation, model analysis, etc.).

In the context of AIDOaRt, the plan is to reuse and extend JTL to support the development of various news features of the tool to contribute to the model-based core set capabilities as well as their application within different AIDOaRt use cases or scenarios.

TWIMO (digital TWin for MOdeling and analysis) is a framework that exploits MDE principles to drive AI/ML augmentation. It offers advanced modeling and AI/ML analysis and validation capabilities, in particular: (i) extending standard domain system language to offer advanced modeling and validation capabilities in the automotive domain, (ii) defining a domain-specific language for the specification of human driver behavior in the automotive domain, to offer advanced modeling and ML analysis capabilities. (iii) providing ML-based analysis and prediction capability on the human driver behavior in the automotive domain.

In the context of AIDOaRt, the plan is to adapt and improve its methodologies and technologies with the scope to integrate them in the DevOps practices. UNIVAQ is interested to acquire AI/ML techniques to specifically improve pattern detection and correlation to more widely support the designer in the continuous improvement of software through the exploration of the effects of automated refactoring actions. In this respect, gathering feedback from the application of such technologies to real life complex CPSs may represent a compelling source of improvement. UNIVAQ aims to improve its data correlation techniques by exploiting AI/ML for the automated association of design and runtime information.

[13] http://jtl.univaq.it/

Conclusions

The paper describes the AIDOaRt approach to maximize the benefit of the project results by applying the developed technologies and tools on the project industrial case studies and by discovering more opportunities in the industry where the project results can be applied. A selection of the tools that will be extended and used in the context of the overall AIDOaRt approach to respond to the model-base capabilities requirements is also presented including some first analysis of the expected improvements after the first year of the project. As the work in the project progresses, discussions and in-depth negotiations are taking place between case study providers and solution providers. This is leading to precise and concrete use case and data requirements, and better choices and selections of candidate solutions.

Acknowledgement

Special thanks to all AIDOaRt consortium members who are currently working on this project. The AIDOaRt project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 101007350. The JU receives support from the European Union's Horizon 2020 research and innovation programme and Sweden, Austria, Czech Republic, Finland, France, Italy, and Spain.

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