



Project Results

IVVES

Industrial-grade verification and validation of evolving systems

The ITEA project IVVES (Industrial-grade Verification and Validation of Evolving Systems) has developed verification and validation (V&V) tools for evolving systems (ES), allowing artificial intelligence (AI) and machine learning (ML) to be introduced to mission-critical environments.

Today's enormous software growth has fuelled the evolution of evolving systems, including machine learning components that (semi-)automatically adapt to new requirements and conditions. Their use will continue to expand significantly in automation, computation and novel digital services due to fast iteration cycles in development and their learning capabilities, yet this poses a challenge for domains in which quality assurance is critical. To answer evolving systems-related questions on data transparency, trustworthiness and product quality, new V&V approaches are needed.

This is what IVVES set out to achieve, creating the first ever industrial-grade V&V for ES quality assurance. This involved the systematic development of robust, comprehensive V&V for embedded AI, targeting three major outcomes: (1) validation techniques for ML; (2) validation techniques for complex ES; and (3) data-driven engineering. The corresponding tools were developed according to use-case requirements in transportation, finance, healthcare, industrial automation and cyber security. An experimentation platform has also been developed to demonstrate the applicability and usefulness of these tools and techniques. Overall, this will lead to higher-quality products, reduced time-to-market and lower maintenance costs for providers of mission-critical systems and services that would adversely affect individuals, business and society when they fail.

Technology applied

IVVES' most important innovation is that

it is now possible to verify or validate a product with an AI/ML component and release this to a regulated market. This has been realised through various technical achievements, connected via a quality AI framework to enable a complete development cycle. Regarding V&V for evolving systems, IVVES has improved artefacts like models, data and features to boost the general and fundamental testability of AI and has used AI to extend and improve model and search-based testing for better automation, testing efficiency and trustworthiness. Tools include Machine Spraak (for collecting system sound data

agents, identification of operational and behavioural patterns and decision support for maintenance, the latter of which has been applied to existing trains. Another highlight involves synthetic 3D brain data for magnetic resonance (MR) planning; with this tool, automated models of non-existent brains can overcome the lack of (available) data to train algorithms. 18 tools have been created in total and have been made accessible in the online experimentation platform. Additionally, most have been made available open source for immediate application to real issues.

Making the difference

One of IVVES' biggest successes has been much larger domain independence than expected, resulting in high synergy between use-cases and methodologies that can be applied to two or more



^ IVVES developed V&V methods to bring AI to regulated markets

to enable timely part replacement) and Data Quality Wrapper (for automated exploratory data analysis, pre-processing and audio/image file augmentation to ensure high-quality data).

For data analytics in engineering and operations, IVVES has enabled data collection via non-invasive probe

domains. This message to industry on the value of cross-domain collaboration has also resulted in impressive technical advancements. For fault/failure detection and prediction, for instance, the project expected a 30% improvement but hit 50%. Other highlights include a ~70% increase in data/information quality, >30% faster test speeds and >120% greater test

coverage (against expectations of 40%, 20% and 90% resp.)

By expanding ML V&V to critical areas for the first time, IVVES will open up new markets. Across the use-case domains, test automation is set to be worth USD 80 billion by 2032 at a 15% compound annual growth rate and companies of all sizes can increase their competitiveness and market share via open-source AI/ML tools. This translates into greater product availability, reliability and maintainability for end-users. A web crawler tool by ING, Concatel and Netcheck will also provide an environmental, social and governance (ESG) dimension by providing company ratings in these areas to enable better investments.

Commercial and internal benefits will also be felt by the consortium. Philips, for example, has received FDA clearance for its SmartSpeed MR software and expects this to be used in 97% of future clinical examinations. For cyber security, WithSecure has developed a tool suite to automatically analyse test results and feedback provision to increase

confidence in its product releases, while Alstom expects its smart CI/CD data collection, analytics and test automation for transportation to reach TRL8 within three years. This will lead to improved maintenance of legacy train fleets which do not have data collection infrastructure by design.

Having developed a pre-standardisation methodology for data-driven engineering and evolving systems V&V, IVVES is engaged in dissemination via (among other things) 24 PhDs, master's and bachelor's and 31 scientific journals, conferences/symposia and book chapters. With excellent collaboration despite COVID-19, at least three possible consortiums will continue to develop areas of the project such as sound mapping and brain imaging. For the near future, the results will lead to further improvements in testing speed and coverage and new tools for AI/ML applications in regulated environments. In the long term, self-learning tools will be introduced to such environments and IVVES will help pave the way to this breakthrough.

Major project outcomes

Dissemination

- > 5 scientific journals, 25 conferences & symposia, 1 book chapters, >11.000 impressions on LinkedIn; >450 views on YouTube: Advent calendar (advent.ivves.eu)
- > 18 trainings (online/on-demand); content also in academic curricula (OU, UoH, TU/e)
- > 5 PhDs, 13 MScs and 6 BScs (and multiple internships)

Exploitation (so far)

- > Quality AI Framework and Assist Suite: data-driven suite to accelerate development and testing
- > Synthetic 3D brain images for MRI planning: generation of synthetic brain data for training and testing
- > Data collection from legacy systems; modern diagnostics for legacy train fleets
- > Flaky test detection: Simplify test result analysis through monitoring state changes
- > Scriptless GUI testing: Enhancements of the Testar tool
- > MACAU: Prediction of trustworthiness with non-linear models
- > Machine Spraak: Audio analysis for predictive maintenance
- > Model cards: Continuous documentation for describing ML models
- > DSI visualization: Multi-class identifiers for understanding decisions made by AI
- > See YouTube for explanation and more tools: <https://bit.ly/3lcaKz6>

Standardisation

Participation in and contribution to ISO/IEC JTC 1/ SC 42 "Artificial intelligence":

- > ISO/IEC JTC 1/SC 42/WG 2 Big Data
- > ISO/IEC JTC 1/SC 42/WG 3 AI Trustworthiness
- > ISO/IEC JTC 1/SC 42/WG 5 Computational approaches and computational characteristics of AI systems

ITEA is the Eureka R&D&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).

<https://itea4.org>

IVVES

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Partners

Canada

- > Centre de recherche informatique de Montréal
- > RHEA Technologies Lab

Finland

- > Futurice
- > HeadAI
- > Solita
- > Techila Technologies
- > University of Helsinki
- > VTT Technical Research Centre of Finland
- > WithSecure Corporation

The Netherlands

- > ING Bank
- > InnSpire
- > Marviq
- > Philips
- > Praegus
- > Sogeti Nederland
- > The Open University of The Netherlands

Spain

- > Keyland Sistemas de Gestión
- > NETCheck
- > SII CONCATTEL

Sweden

- > ABB
- > Addiva
- > ALSTOM Rail Sweden
- > Ekkono Solutions
- > RISE - Research institutes of Sweden

Project start - Project end

October 2019 - December 2022

Project leader

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