Synthetic Data for Autonomous Earthworks in Civil Construction

SynDAB is a validated technology that enables the generation of structured, synthetic training and test data for autonomous construction machinery. By simulating real-world conditions such as earthworks, slopes, and environmental clutter in Unreal Engine and ROS, SynDAB provides AI-ready datasets for system training, validation, and certification.

- Eliminates the need for costly, high-risk real-world testing
- Enables simulation of rare and hazardous corner cases
- Closed-loop validation pipeline with requirements traceability
- Supports standards-based evaluation and performance metrics

Fields of application

- Autonomous excavators, graders, and trenchers
- Earthmoving robots for civil infrastructure projects
- Robotics platforms for construction automation

TLB
Technologie-Lizenz-Büro
der Baden-Württembergischen
Hochschulen GmbH

Kontakt
Dipl.-Ing. Julia Mündel
TLB GmbH
Ettlinger Straße 25
76137 Karlsruhe | Germany
Telefon (49) 0721 / 79004-37
muendel@tlb.de | www.tlb.de

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Service
Technologie-Lizenz-Büro GmbH has been entrusted with exploiting this technology and assisting companies in obtaining licenses.

Background

The construction industry is rapidly adopting autonomous and semi-autonomous systems for tasks such as excavation, grading, and site surveying. However, these systems operate in dynamic and often hazardous environments where access to diverse, high-quality training and testing data is limited. Traditional field testing is time-consuming, expensive, and often fails to capture rare but critical edge cases. Furthermore, certifying these systems to meet related safety standards requires reproducible testing and traceable validation, which current methods struggle to deliver.

The invention originates from the Institute of Industrial Automation and Software Engineering (IAS) at the University of Stuttgart, under the direction of **Prof. Michael Weyrich** (Institute Director) and **Prof. Christof Ebert**. Their research focuses on AI-based testing and validation of autonomous and safety-critical systems in complex environments.

The project builds on prior work in the field of simulation-based validation for autonomous systems and software quality assurance.

Problem

Validating autonomous systems for construction requires large-scale, scenario-rich datasets which are not readily available. Real-world data collection is dangerous, expensive, and often incomplete, especially for safety-critical or failure-prone situations. Certification processes remain lengthy due to a lack of reproducibility, traceability, and robust simulation tools.
Furthermore, construction sites involve constant environmental changes, multi-machine interactions, and unpredictable human factors, making it extremely difficult to replicate key scenarios for testing consistently. As a result, developers face high costs, long validation cycles, and limited regulatory clarity.

Solution

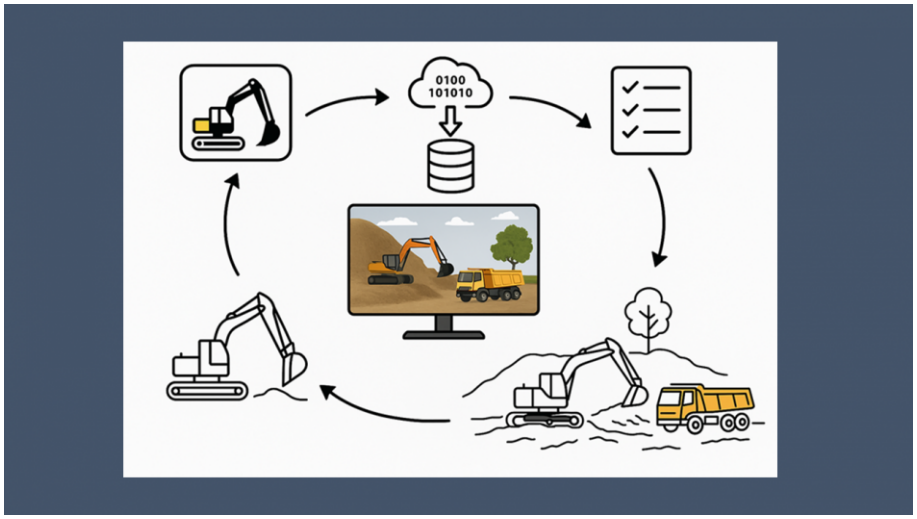
The University of Stuttgart has developed and patented an AI-based validation framework that enables the targeted simulation of operational and failure scenarios in construction environments. The system generates synthetic sensor data across various terrain types and dynamic site conditions, reducing the need for high-cost and high-risk physical testing.

By using artificial intelligence, the platform creates a Minimum Viable Test Set (MVTS) consisting of risk-prioritized scenarios, significantly reducing the number of real-world tests required for system validation. These scenarios replicate safety-critical interactions between autonomous machinery and unpredictable site conditions, enabling traceable and reproducible assessments.

The system supports integration with digital twins and test platforms and aligns with standards such as ISO 17757, ISO 13849, and PAS 1883. It accelerates development, supports regulatory compliance, and enables scalable validation of

AI-driven construction technologies.

This technology can be transferred to industry through licensing, which provides a straightforward commercialization pathway. Alternatively, the inventors' team at the University of Stuttgart has implemented several algorithms in software that can be adapted and extended through cooperation or consulting projects, allowing tailored applications for specific industrial use cases.



A visual workflow showing the SynDAB system for autonomous construction machinery: AI training starts from scenario generation and synthetic data creation in simulation, followed by testing against KPIs, real-world application, and data-driven system refinement in a closed validation loop. [Image: AI-created by TLB GmbH]

Publication and links

Ebert, C. et al. (2023). AI-Based Testing for Autonomous Vehicles. ResearchGate link

IAS (2022). Testing Software Systems. University of Stuttgart. Link

Synthetic data generation for the continuous development and testing of autonomous construction machinery, Alexander Schuster, Raphael Hagmanns, Iman Sonji, Andreas Löcklin, Janko Petereit, Christof Ebert, and Michael Weyrich. Link