Off-Road Synthetic Training for Agricultural Robotics

SynDAB offers a flexible simulation platform for generating synthetic datasets tailored to agricultural environments. It supports AI-based navigation, obstacle detection, and object classification in variable terrain and weather conditions, without needing seasonal field access.

- Synthetic data generation independent of agricultural seasons
- Wide coverage of terrain and crop conditions
- Integration with real AI modules and agricultural sensors
- Enhances AI training with rare and edge-case situations

Fields of application

- Autonomous tractors and harvesters
- Field robotics for fruit picking, plowing, spraying
- Agri-tech startups and AI module developers

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

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

Development Status
TRL 3

Patent Situation
EP 3832549 (UP) granted
EP 3832548 (UP) granted
EP 3832548 (GB, ES, CZ) granted

Reference ID
19/006TLB_Agriculture

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

Background

Agricultural robotics must perform reliably across highly variable environments, including changing terrain, crop types, weather patterns, and seasons. However, real-world field testing is limited by seasonality, high costs, and unpredictable biological variability. This restricts the ability to train and validate AI algorithms for navigation, perception, and action planning. Moreover, current certification frameworks for agricultural automation require validation under a range of Operating Design Domains (ODDs), necessitating simulation-driven approaches to achieve regulatory confidence.

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

This invention extends their simulation-based validation framework to agricultural robotics, enabling synthetic training and testing under diverse terrain, crop, and weather conditions. By eliminating seasonal constraints, it supports continuous AI development and regulatory validation for next-generation agricultural automation.

Problem

Agricultural robotic systems are currently validated through extensive field testing, which is expensive, weather-dependent, and constrained by seasonal crop cycles. This delays development and restricts exposure to a broad range of operational conditions necessary for robust AI performance.
Edge scenarios such as sudden terrain changes, equipment failure, or crop variability are complex to reproduce in natural settings. Without intelligent scenario selection and synthetic sensor data generation, agricultural automation struggles to meet regulatory requirements or achieve commercial scalability.

Solution

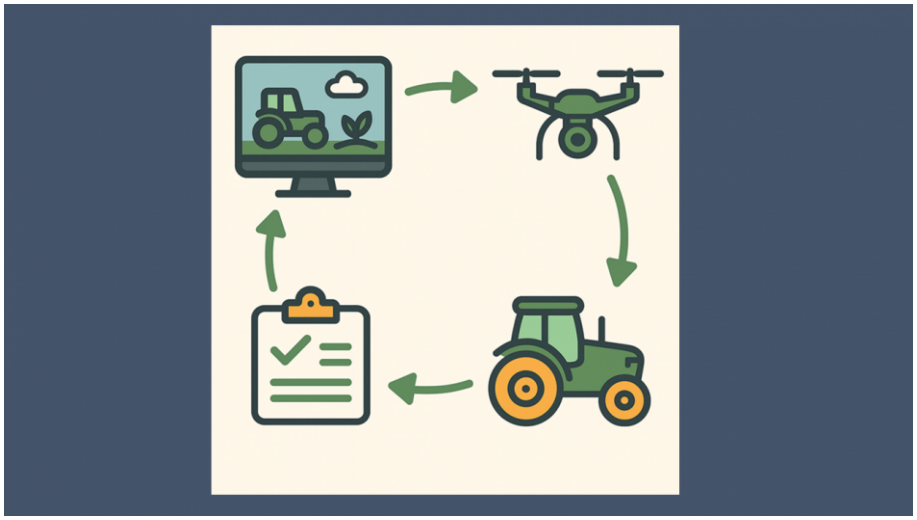
Autonomous systems in agriculture benefit from this AI-powered simulation platform by enabling virtual validation of complex and seasonal conditions that cannot be captured year-round. The SynDAB system models crop variability, soil types, terrain obstacles, and weather impacts to generate synthetic training and validation data.

By using intelligent selection of relevant scenarios, the system creates a Minimum Viable Test Set (MVTS) that targets risk-based validation, including edge cases such as unexpected terrain changes or equipment failure. The technology enables digital twins of farming operations and can integrate into existing farm automation testing platforms.

It supports alignment with ISO 25119 (functional safety for agricultural

machinery), ISO 18497 (safety of autonomous machines in agriculture), and other performance validation guidelines. The system offers a reproducible, standards-aligned testing method for safer, more scalable agricultural robotics.

The technology can be transferred to industry through licensing, enabling direct adoption by agricultural equipment manufacturers and automation developers. Alternatively, the inventors' team at the University of Stuttgart offers cooperation or consulting projects, where existing software modules and simulation algorithms can be tailored to specific agricultural use cases, such as precision farming, autonomous field robotics, and farm digital twins.



A symbolic representation of the SynDAB system applied to agriculture: integrating simulated farm environments, sensor-equipped autonomous tractors, variable terrain and weather, and an iterative AI training loop to improve navigation, object detection, and system resilience.[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