Application of Artificial Intelligence in Agricultural Machinery and Components

*by He Z. (Aarhus University, Denmark; Session Rapporteur) and Gay P. (*University Torino, Italy*; Session Chairman).*

Introduction and general overview

The session opens with greetings and an overview of the day's agenda, focusing on the application of artificial intelligence (AI) in agricultural machinery and components. Chaired by Professor Paulo Guy from the Università di Torino. The session frames AI as a technology uniquely suited to operating in unstructured, complex, and uncertain agricultural environments, emphasizing its defining capability of inference, as formalized by the EU AI Act—namely, generating predictions, recommendations, or decisions that influence physical systems based on data-driven models. Inference alone is insufficient to qualify as AI, highlighting autonomy, adaptability, and learning from data as essential characteristics.

The session's objective is to address key open questions, including how AI can be effectively integrated into agricultural engineering, how it can enhance productivity and safety, when AI systems become high-risk, how certification and homologation should be managed, how to deal with self-evolving and continuously learning systems, and whether the industry is ready for AI-based autonomous agricultural machines, while setting the stage for technical, regulatory, and practical discussions by four invited speakers: Happich G. (University Applied Scinces Kempten - Germany), Bolognesi A. (FederUnacoma - Italy), Bertogna M. (University Modena-Reggio Emilia - Italy) and Parazza D. (KIWITRON - Italy).

1. Talk 1: AI in Agricultural Engineering. Reality, Limits and Outlook

by Happich G. (University of Applied Scinces Kempten - Germany)

Prof. Dr. Georg Happich, University of Applied Scinces Kempten - Germany, opens with an accessible analogy comparing AI learning to how children learn to ride bicycles—not through explicit mathematical modeling, but through trial, error, adaptation, and trust. This highlights the non-deterministic, adaptive nature of AI distinct from classical engineering approaches.

Evolution of Agricultural Engineering:

- Mechanization: Introduction of tractors and machines to amplify human labor.
- Automation: Repetitive tasks automated to improve efficiency.
- Digitization: Integration of electronics and computers for precision and control.
- AI as Evolution: AI is not just a next step but a paradigm shift, enabling machines to handle uncertain, variable environments adaptively.

Current AI Applications in Agriculture:

- Precision weeding robots that identify and treat weeds selectively, reducing chemical use and labor intensity.
- Smart spraying systems that activate nozzles based on plant recognition, improving sustainability.
- Livestock health and welfare monitoring through behavioral analysis and early disease detection.
- Post-harvest applications such as sorting and grading using image recognition.
- Decision support systems for yield forecasting and crop management.

Challenges and Limitations:

- Environmental conditions like light, dust, and soil variability affect sensor accuracy.
- Hardware robustness and cost hurdles persist; AI hardware can be expensive and less durable than traditional embedded systems.
- Explainability and trustworthiness are crucial for acceptance, as AI systems are inherently non-deterministic.
- Paradigm shift in engineering: AI requires defining context rather than explicit rules, and verification relies on statistical confidence rather than deterministic pass/fail tests.

Data as the Core Resource:

Prof. Happich stresses data quality, ownership, annotation consistency, and interoperability as key challenges. Data fragmentation and reluctance to share data between manufacturers and platforms hinder AI development. He calls for standardization efforts and collaboration to overcome these issues and invites Alessio Bolognio to address regulatory frameworks.

2. **Talk 2: AI in Agricolture: Rushing Between Challenges and Opportunities**

by Bolognesi A. (FederUnacoma - Italy)

Mr. Alessio Bolognesi, responsible for digital agricultural affairs in FederUnacoma, frames the regulatory environment in which AI-powered agricultural machinery operates, focusing on European legislation:

- **AI Act EU-2024:1689**: Introduces broad definitions and classifications of AI systems, with a risk-based approach. High-risk AI systems require rigorous third-party certification.
- **Machinery Regulation EU-2023:1230**: Updated to include software and AI as part of safety components, creating overlap and complexity in compliance.
- **Cyber Resilience Act EU2024:2847**: Addresses cybersecurity requirements across a product's lifecycle, emphasizing safety by design and vulnerability management.
- **Data Act EU-2023:2854**: Governs data access, sharing, and portability, affecting how agricultural data flows between manufacturers, platforms, and farmers.

Challenges for Industry:

- Overlapping regulations create confusion and duplicated conformity assessment processes.
- Liability issues arise around AI self-evolving systems and responsibility between manufacturers, software providers, and users.
- Technical challenges include ensuring safety and security integration, plus managing lifecycle compliance with over-the-air updates.
- Standards for AI data annotation, interoperability, and safety are lagging behind regulatory timelines, complicating implementation.

Standardization Efforts:

- The agricultural sector benefits from prior ISO standards like ISOBUS but must expand to cover AI-specific needs for data and safety.
- Initiatives like the Agriculture Interoperability Network and new ISO Technical Committees are working on standardized data models and transfer protocols.
- Functional safety and cybersecurity standards are being updated to incorporate AI considerations.
- Despite challenges, AI is inevitable and presents significant opportunities for innovation in agricultural machinery. Europe must act collaboratively to remain competitive in this rapidly evolving field.

Mr. Bolognio concludes that despite challenges, AI is inevitable and presents significant opportunities for innovation in agricultural machinery. Europe must act collaboratively to remain competitive in this rapidly evolving field.

3. Talk 3: Embedded AI for Application in Real-time

by Bertogna M. (University Modena-Reggio Emilia - Italy)

Prof. Dr. Marko Bertogna, University of Modena, discusses the practical challenges and technological advances enabling embedded AI in agricultural machinery:

Current Landscape:

- The exponential growth of computing power has made it feasible to embed AI in small, low-power devices suitable for machinery.
- Autonomous driving, a related domain, highlights the complexity and scale of investment required billions of dollars have been spent with many failures.
- Unlike automotive giants with massive budgets, European agriculture-focused entities must innovate smartly with constrained resources.

Technical Challenges:

- Autonomous systems require multisensory data fusion (cameras, LiDAR, radar, GPS), real-time processing, localization, mapping, perception, decision-making, and control.
- Safety is paramount; systems must operate reliably in diverse and changing environments.
- Simulation and virtual testing are critical due to limited real-world testing opportunities and cost.
- Software development cycles are fast and require continuous updates via over-the-air mechanisms.

Market and Industrial Ecosystem:

- The market potential for embedded AI in agriculture is huge but demands collaboration between academia, industry, and startups.
- Europe must overcome fragmentation and invest strategically to compete with US and Chinese players.
- AI and autonomous capabilities will transform agriculture by addressing labor shortages and enhancing productivity, but full autonomy is still years away.

Prof. Bertogna closes with optimism about Europe's technological capabilities but emphasizes the need for open innovation, partnerships, and a united approach to capture the AI opportunity in agriculture.

4. Talk 4: The Use of AI for Productivity and Safety in Agricultural Machinery

by Parazza D. (KIWITRON - Italy)

Mr. Daniele Paratza, the co-founder and chief technology officer of KIWITRON, a company specializing in safety assistant solution to industrial and agricultural machinery, presents practical AI applications focusing on safety enhancement and productivity in agricultural machinery from Kiwitron's perspective:

Company Background:

- Kiwitron, founded in 2019, develops safety assistant solutions using radar, radio, vision, and AI technologies.
- Their solutions aim to balance safety and productivity for machinery operators.

Example Applications:

- AI-powered vision systems on tractors monitor the surroundings, detecting people and obstacles with stereo vision to estimate distance and trigger warnings or interventions.
- Safety systems include multi-level alerts via visual (LED) and auditory signals to protect operators and bystanders.
- Crop line detection and plant mapping systems collect data passively or actively to support precision tasks and farm management.

AI Principles and Challenges:

- AI differs from traditional software by learning from data rather than following predefined rules, allowing adaptability in complex environments.
- Models are probabilistic, not deterministic, meaning outputs have associated confidence levels and can produce errors (e.g., misclassifying objects).
- Continuous model maintenance, dataset updates, and monitoring in real-world conditions are crucial for reliability and compliance.

Regulatory Context:

- AI Act categorizes AI systems by risk (minimal, limited, high, prohibited), with compliance requirements scaling accordingly.
- Limited risk systems mostly require transparency, while high-risk systems demand rigorous quality management and tracking.
- Kiwitron offers ready-to-integrate solutions designed for out-of-the-box compliance to ease adoption.

Advice for Industry:

- Start with low-risk AI applications to gain experience and build confidence.
- Balance cost and benefits for end users, ensuring systems are practical and affordable.
- Recognize AI's permanence and embrace gradual integration to enhance safety and productivity.

5. Panel Discussion: Ethical, Technical, and Practical Challenges of AI in Agriculture

The panel discussion addressed a range of ethical, technical, and societal questions raised throughout the session. Regarding concerns about superintelligent AI, panelists emphasized the importance of first achieving reliable, "almost human" AI performance in specific tasks. They noted that narrow AI systems already outperform humans in areas such as pest detection without posing broader ethical risks.

Ethical and safety considerations centered on the need for built-in safeguards to prevent harmful behaviors and mitigate cybersecurity threats. Liability was identified as a major unresolved issue, particularly for self-evolving systems where responsibilities are distributed across multiple stakeholders.

User acceptance emerged as a critical factor for successful deployment. Farmers expect intuitive, reliable human–machine interfaces, and trust must be built through transparency, gradual introduction of AI features, and clear communication of system limitations. Education and demonstration of tangible benefits were seen as key to overcoming reluctance to cede control of AI systems.

The discussion also highlighted the importance of continuous data collection and model retraining—the so-called data flywheel—for improving performance over time. While open-source models and datasets are widely used, they require careful validation to meet regulatory requirements. The panel concluded by acknowledging the complexity of AI integration but emphasized that continued dialogue, research, and collaboration are essential for progress.

6. Key Insights from the Session:

The session clearly demonstrated that AI in agriculture has moved beyond theoretical exploration and is now being actively integrated into robotics, crop management, livestock monitoring, and safety systems. This transition from classical engineering to AI-driven solutions necessitates a fundamental shift in design philosophy, validation methods, and trust-building practices. Data quality, interoperability, and sharing remain critical bottlenecks, requiring coordinated standardization efforts. While European regulatory frameworks are evolving rapidly, overlapping rules and unclear liability—particularly for self-learning systems—pose significant challenges. Advances in computing power have made embedded AI increasingly feasible, but careful consideration of cost, safety, and scalability is essential. Ultimately, user acceptance depends on intuitive interfaces and education, and sustained collaboration among academia, industry, and regulators will be crucial to advancing safe, ethical, and effective AI applications in agriculture worldwide.

Key sentences for S.3 from members in Club of Bologna:

Prof. Lazar Savin (University Novi Sad, Serbia):

- AI is already used in all agrotechnical operations and processes accompanying food production, which enables the implementation of Agriculture 5.0. In the future, we should expect a wider application of autonomous machines.
- In order to fulfill the ethical requirements when using AI, it was necessary to pass several regulations and laws, but work on the development and adoption of new ones should continue. Effective AI requires accurate data, control traceability and personal responsibility of the designer.

Prof. Gennaro Giametta (University Reggio Calabria, Italy):

- Even if its diffusion seems premature, A.I. can be introduced in agricultural machinery and especially in the individual components of the machines.
- The employ of use of AI involves a series of rules in the technology to safeguard the health and rights of users.

Prof. Hermann Auernhammer (Technical Univ. Munich, Genmany):

- Whatever is associated with AI, its real value is based exclusively on training data, and in agriculture, this data is always the property of the farmer. Therefore, the value of this data must be defined by science and implemented in practical examples.
- The practical application of AI in stables and/or fields requires real-time data in a standardized form, however that may be defined. Here, too, scientists are called upon to define the necessary standards and evaluate them in consultation with AI users.

Prof. Pierluigi Febo (University of Palermo, Itlay):

- Nowadays the use of AI in agriculture is very low in comparison with its potential application to improve agricultural automation.
- Autonomous tractors, weeding, seeding and pest control robots, are only some examples of AI's potential application in the near future.

Prof. Josse De Baerdemaeker (KU Leuven, Belguim):

- AI in agriculture (as in many fields) needs rules and trust. The question is to what level these rules can be part of a legal framework and where the industry takes a fair responsibility in the benefits and risks that takes into account the different level of familiarity with AI that exists between the industry and the customers, the farming community.

- Embedding AI in autonomous agricultural machinery looks very promising, but in reality the business models and the balance between hardware and software in those machines are undergoing rapid changes. Yet field conditions may require that mechanical or mechatronic robustness of the machinery is guaranteed, even when these autonomous machines may look small and fragile.

7. Conclusion

This comprehensive session provided a multi-faceted view of AI's role in transforming agricultural machinery, from conceptual frameworks and regulatory challenges to practical applications and future outlooks. While significant hurdles remain in technology, regulation, and social acceptance, the collective expertise and collaborative efforts showcased offer a promising path forward for AI-enhanced agriculture.