ICPR 2026 - MCMI Workshop

Detect, Anticipate, and Explain Anomalies in Agricultural Robots: A Review

Thomas Trouvé
INRAE, Neusta
Co-authors: Damien Appert, Riccardo Bertoglio, Sandro Bimonte, Jocelyn De-Goer-De-Herve

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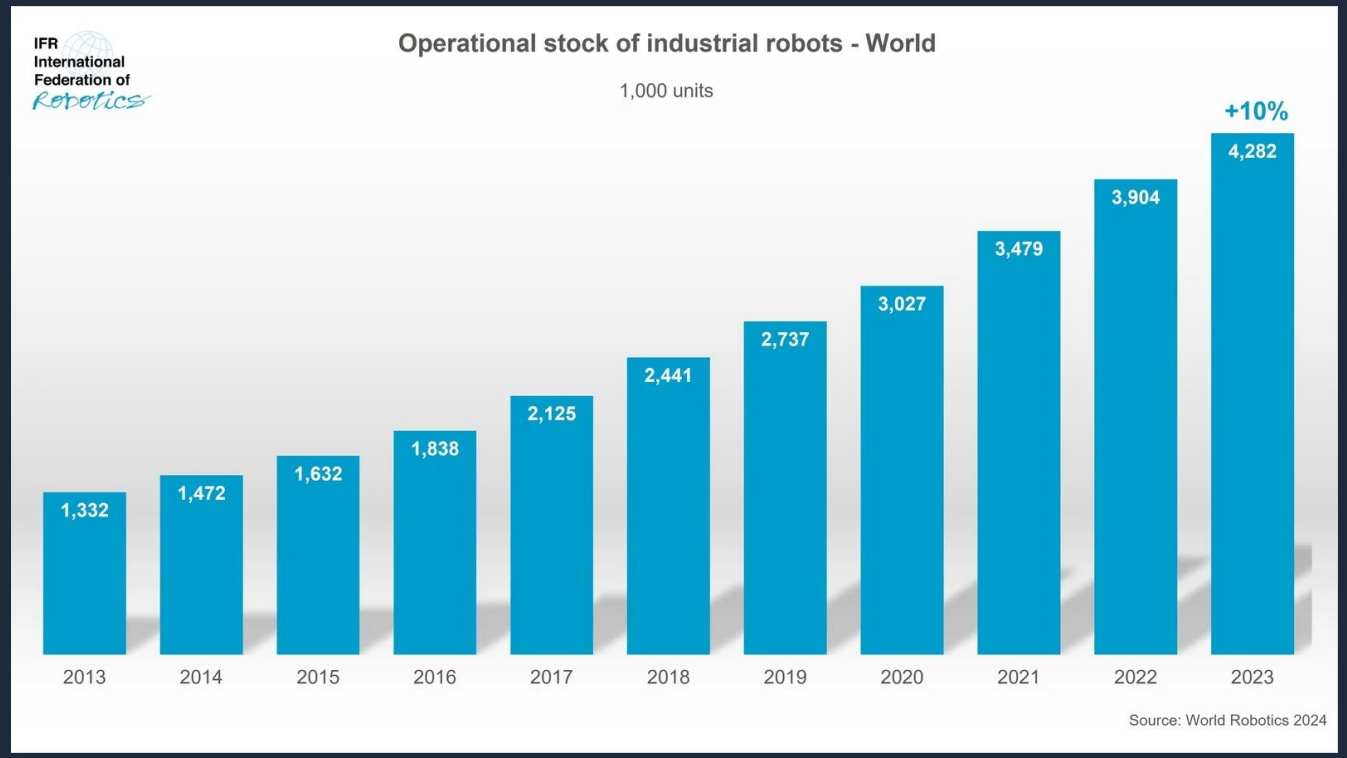
1. Context

- Robots are increasingly deployed beyond controlled environments
- Agriculture is one of the major domains for autonomous robotics
- Unlike industrial robots, agricultural robots face unpredictable environments



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2. Motivation

- Unexpected anomalies are inevitable during field operation

Risk of :

- Operational failure
- Hardware damage
- Downtime

Need for anomaly management:

- Detect
- Anticipate
- Explain

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3. Four Core Challenges in Smart Farming

Data Scarcity

Rare, diverse, and costly-to-collect failures

-> Unsupervised Learning

Multimodal Data

Agricultural Robots rely on heterogeneous sensors

(camera, GPS, IMU)

-> Multimodal Fusion

Ressources & Connectivity

Limited onboard resources and unreliable connectivity

-> Edge AI

Non-Expert Operators

Technical outputs are difficult to interpret

-> Clear, Interactive and accessible explanations

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4. What is multimodality in Robotics?

Human Perception

Different ways of perceiving information

- Vision
- Hearing
- Touch
- ...

Machine learning

Different data representations

- 2D Image
- 1D Signal
- Tokens
- ...

Robotic systems

Multimodality is used inconsistently

- Often confused with multiples sensors
- Multi-sensor ≠ Multimodal
- Multimodal data ≠ multimodal problem & solution

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5. Proposed Framework

Multimodal Data

Presence of fundamentally incompatible structures.

- Structurally incompatible, cannot be merged in their raw state.

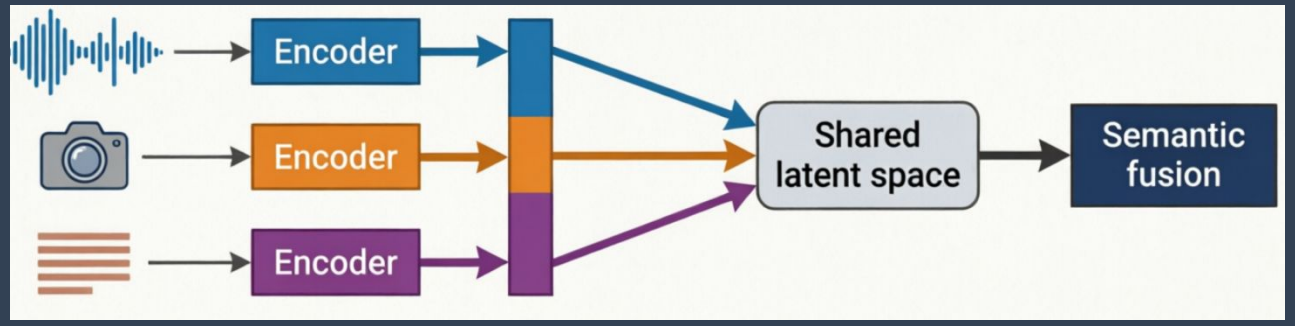
Problem Multimodality

The task requires heterogeneous inputs to be solved

- Not Multimodal: Obstacle detection
- Multimodal: Instruction-guided manipulation

Solution Multimodality

Dedicated modality-specific transformations.



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6. Taxonomy of Robot Anomalies

Internal	External	HRI Anomalies
Hardware Fault	Task Failures	Human Errors
Software Fault	Malicious Faults	Agents Errors
	Environmental Faults	Exchange Errors

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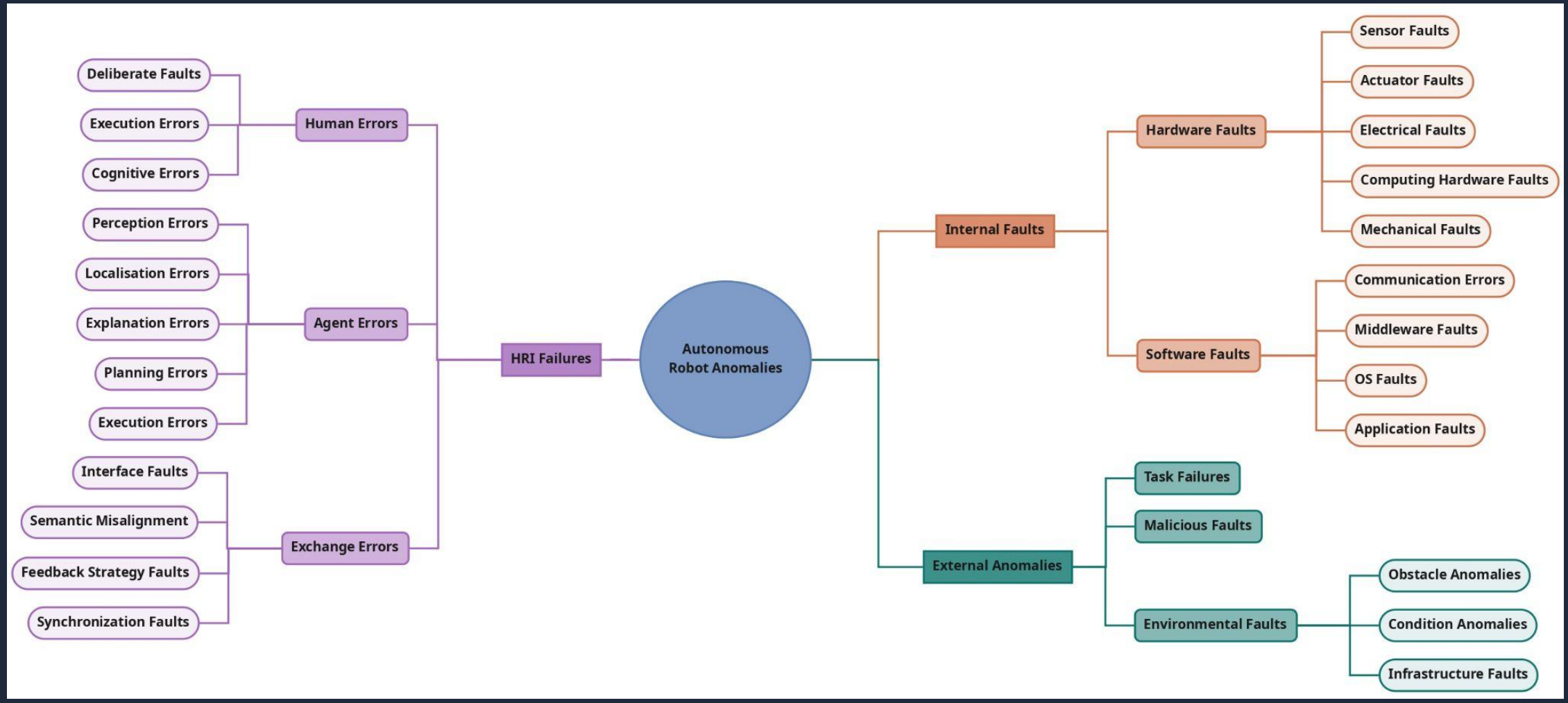
7. A Novel Taxonomy of Robot Anomalies



8. Summary of Reviewed Studies

Article	D	A	E	Sup.	Inputs	Topology	Model	Anomaly Scope
37	✓	✓	×	P	R, T	2D, Tk	CLIP + DINOv2	x(env, task), hri(human, agent)
39	✓	✓	✓	P	Pr, R, T	1D, 2D, Tk	GMR + CondNet	i(hw), x(task), hri(human, agent)
29	✓	×	✓	F	T, R, Dp, Au, Pr	1D, 3D, Tk	CLIP + GPT-4	x(env, task), hri(agent)
36	✓	✓	✓	F	R, T	2D, Tk	GPT-4V	x(task)
20	✓	×	✓	F	T, R, L	2D, 3D, Tk	GPT-4	x(task)
42	✓	×	×	F	R, Dp, Au, Pr	1D, 2D	CNN + DAE	x(task, env), i(hw)
26	✓	×	✓	F	R, T	2D, Tk	GPT-4o + QwenVL	x(task)
23	✓	✓	✓	F	T, R, L, I, G	1D, 2D, 3D, Tk	Llama2-13B	x(env), hri(agent, exch.)
35	✓	×	×	F	R, Pr	1D, 2D	Autoencoder	x(env), i(hardware)

9. Modalities & Sensors

- **RGB Cameras:** The foundational modality, appearing in 100% of the reviewed studies.
- **Text Inputs:** 2nd most common. Driven by LLMs acting as semantic bridges.
- **Proprioception & Depth:** Frequently used in manipulation tasks but underutilized globally.
- **Navigation Sensors:** LiDAR, IMU, and GPS used fot navigation tasks.
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10. Application Domains

Object Manipulation

Most explored domain. High performance in controlled environments, but highly **task-specific**.

Autonomous Navigation

Real-time reactive planning. Operates in less controlled settings, closer to **agricultural constraints**.

General Monitoring

Summarizes robot experiences. Clear trend towards versatile, **multi-task frameworks**.

11. Identified Research Gaps

Reactive Systems

Reactive anomaly management

Detection after failure

Explainability

Moving from binary alerts to rich, **natural language explanations** and automated correction plans.

Physics Blindness

Limited understanding of robot dynamics

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12. Future Research Directions

Two-Speed Architectures

- Fast: Real-time detection.
- Slow: Contextual explanation.

Small Edge Agents

Offline, lightweight natural-language assistance.

World Models

Simulating environments for proactive forecasting.

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Thank You for Your Attention

Thomas Trouvé

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