SummerSOC
Service Oriented Computing

19th Symposium and Summer School On Service-Oriented Computing

Digital Twins: state–of–the–art, use cases and new trends

Part 2

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Introduction

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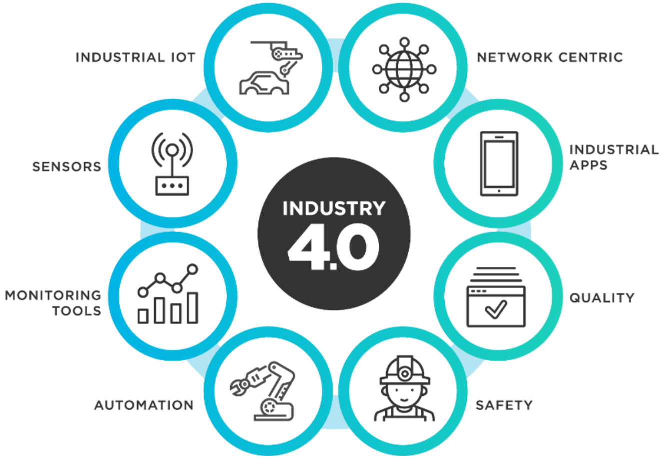
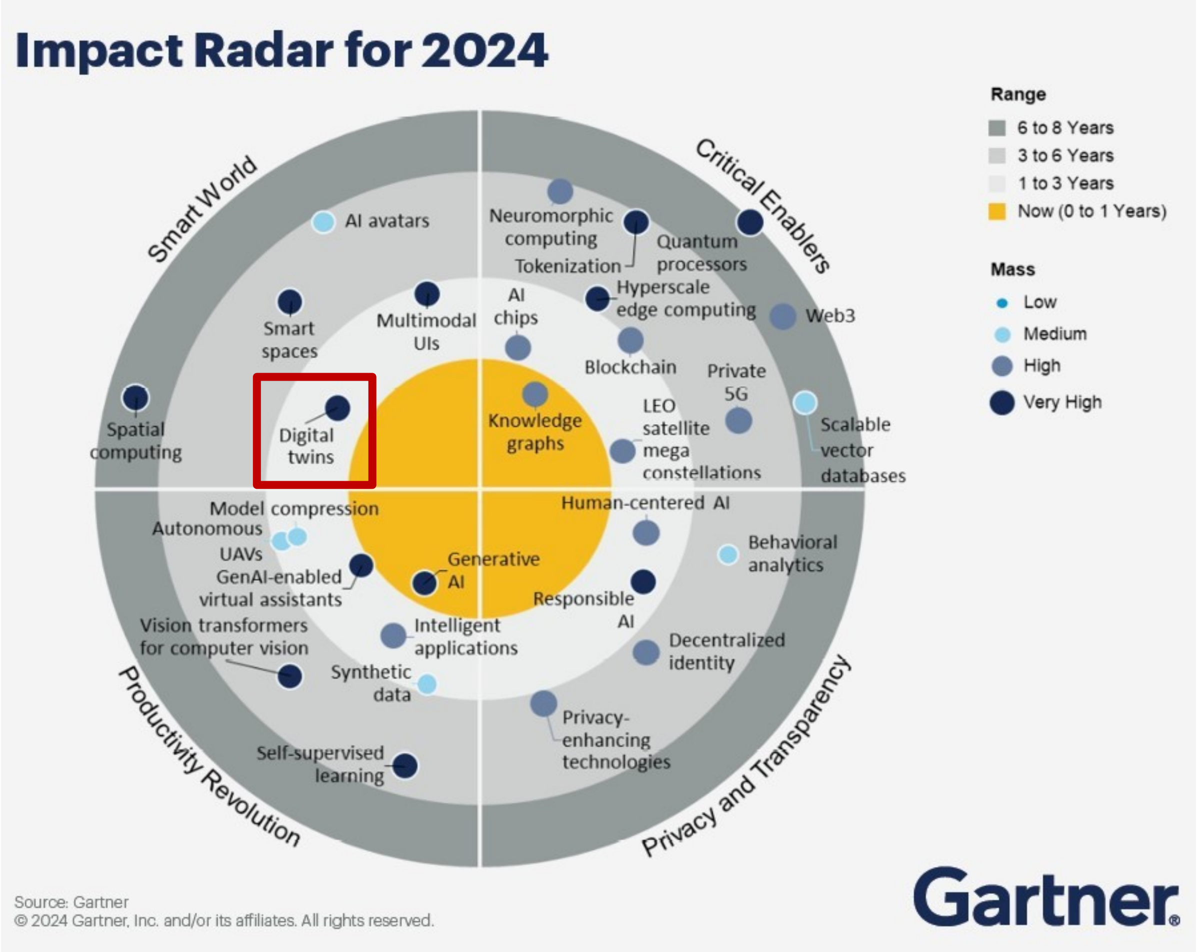


Their potential benefits:

- Optimized operations through real-time control
- Better decisions using simulated future states

Introduction

Digital Twins: Opportunities & Growing Adoption



Introduction

Digital Twins: Opportunities & Growing Adoption

Despite growing interest, widespread deployment is limited. The reasons are both technical and practical.

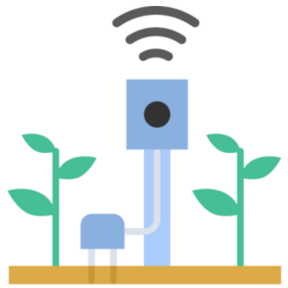
1. **Sensorization and data collection**
2. **Fragmentation of development tools**
3. **High entry barrier and skill requirements**
4. **Lack of reusable models and standardization**
5. **Security and data governance**

Introduction

Digital Twins: Opportunities & Growing Adoption

1. Sensorization and data collection

- Most existing infrastructure is not sensorized.
- Real-world environments are noisy, dynamic, and expensive to monitor.
- Installing sensors involves:
  - Technical expertise
  - Power supply and communication planning
  - Environmental constraints (e.g., weather, location access)
  - More investment



Introduction

Digital Twins: Opportunities & Growing Adoption

2. Fragmentation of development tools

- Many platforms exist, but:
  - There is no unified standard for Digital Twin modelling.
  - Most solutions are ecosystem-dependent (e.g., Azure, AWS, Siemens).
  - Tools often don’t communicate easily with each other.
- Development often requires:
  - Manual data integration
  - Specialized training for each tool and extra services

Introduction

Digital Twins: Opportunities & Growing Adoption

3. High entry barrier and skill requirements

- Developing a DT is not plug-and-play:
  - Requires skills in IoT, cloud services, software architecture, data science, and AI.
- Small companies lack the workforce to adopt/develop these systems.
- Open-source solutions (e.g., Eclipse Ditto) reduce costs but increase technical complexity.

Introduction

Digital Twins: Opportunities & Growing Adoption

4. Lack of reusable models and standardization

- Most DT projects are custom-made, one-off solutions.
- Models are not easily portable or interoperable.
- There's a lack of:
  - Reference architectures
  - Model libraries
  - Semantic standards (though efforts like DTDL and W3C WoT are growing)

Introduction

Digital Twins: Opportunities & Growing Adoption

5. Security and data governance

- Real-time digital twins deal with critical infrastructure and private data.
- Exposing systems to the internet introduces risks:
  - Cyberattacks
  - Data breaches
  - Regulatory non-compliance
- Many organizations are not prepared to manage cybersecurity in complex IoT + AI systems.

Introduction

Session Goals of Part 2

- Review the most prominent tools available today for building Digital Twins.
- Compare their features, strengths, and limitations.
- Demonstrate with a practical application through a real-world traffic case: “Digital Twin of the Madrid M-30 highway”
- Showcasing use cases and new trends on Digital Twins

2. Commercial Tools

Commercial tools

Evaluating Digital Twin Platforms

Explore several industry-recognized platforms designed for creating and managing Digital Twins.

Tools include a mix of:

- Commercial cloud platforms
- Open-source frameworks
- Industrial engineering suites

Commercial tools

A lot of DT commercial tools:

SIEMENS

AWS IoT TwinMaker

ORACLE

ditto

thingworx®

Commercial tools

Azure Digital Twins

- Cloud-native platform for modeling physical environments as graphs of digital entities.
- Built on DTDL (Digital Twins Definition Language).
- Deep integration with Azure ecosystem: IoT Hub, Functions, Event Grid, 3D Scenes, Azure ML.
- Real-time event-driven architecture ideal for:
  - Smart buildings, transportation, manufacturing.
- **Key strengths**:
  - Real-time telemetry and control.
  - Visualization via Azure Digital Twins Explorer and 3D Scenes Studio.
  - Predictive capabilities through Azure Machine Learning.

Commercial tools

Siemens Digital Twins

- Part of the Siemens ecosystem, which integrates PLM, simulation, and IoT.
- Designed for multi-domain simulation: structural, thermal, fluid, electrical, and system-level modeling.
- Testing of industrial equipment.
- Use in aerospace, automotive, mechanical engineering, and heavy industry.
- **Key strengths:**
  - Extremely accurate physics-based modeling.
  - Deep integration with CAD/CAE tools.
  - Provides a full Digital Thread, enabling traceability from design to operation.
  - Trusted in industries requiring mission-critical reliability.

Commercial tools

AWS IoT Twinmaker

- Scalable platform for building digital twins using AWS's existing infrastructure.
- Data sources supported: AWS IoT Core, S3, Kinesis, Lambda, SiteWise.
- 3D visualization enabled.
- Ideal for: Large-scale industrial applications with globally distributed assets like Azure
- **Key strengths:**
  - Strong event routing via EventBridge.
  - Low-latency processing through Lambda functions.
  - Tight integration with AI services (SageMaker, Lookout).
  - High availability and multi-region deployment.

Commercial tools

Oracle Digital Twin

- Built on Oracle Cloud Infrastructure (OCI). Integrated with Oracle Enterprise Asset Management.
- Specializes in asset-intensive industries requiring operational intelligence and predictive maintenance.
- Optimization of enterprise workflows tied to supply chain and maintenance.
- Business-oriented twin integration across ERP and logistics systems.
- **Key strengths:**
  - Embedded AI capabilities for anomaly detection and forecasting.
  - Seamless orchestration between IT systems and physical assets.
  - Comprehensive dashboards and reporting tools for decision-makers.

Commercial tools

Eclipse Ditto

- Framework for managing Digital Twins as JSON-based "Things".
- Implements APIs for real-time and asynchronous interaction.
- Built with microservices, suitable for Kubernetes and Docker environments.
- Can be integrated with external systems: Grafana, PostgreSQL, Mosquitto,…
- Ideal for: open-source projects, custom industrial integrations or academic research.
- Key strengths:
  - Lightweight and highly customizable.
  - Open source, no vendor lock-in.
  - Cost-effective for smaller organizations or research institutions.

Commercial tools

PTC ThingWorx

- Full-featured platform for IoT application development with integrated AR (Augmented Reality) capabilities.
- Strong industrial connectivity through Kepware (OPC, PLC, SCADA).
- Provides low-code tools like Mashup Builder to quickly design interactive dashboards.
- Typical applications: Remote monitoring and control of manufacturing systems. AR-based maintenance and training applications. Lifecycle management of connected devices and equipment.
- **Key strengths:**
  - Native support for AR to overlay live sensor data on physical objects.
  - Rich connectivity with industrial automation protocols.
  - Focused on user experience and rapid UI development.

2. Case Study: Madrid M-30

Case Study: Madrid M–30

M–30

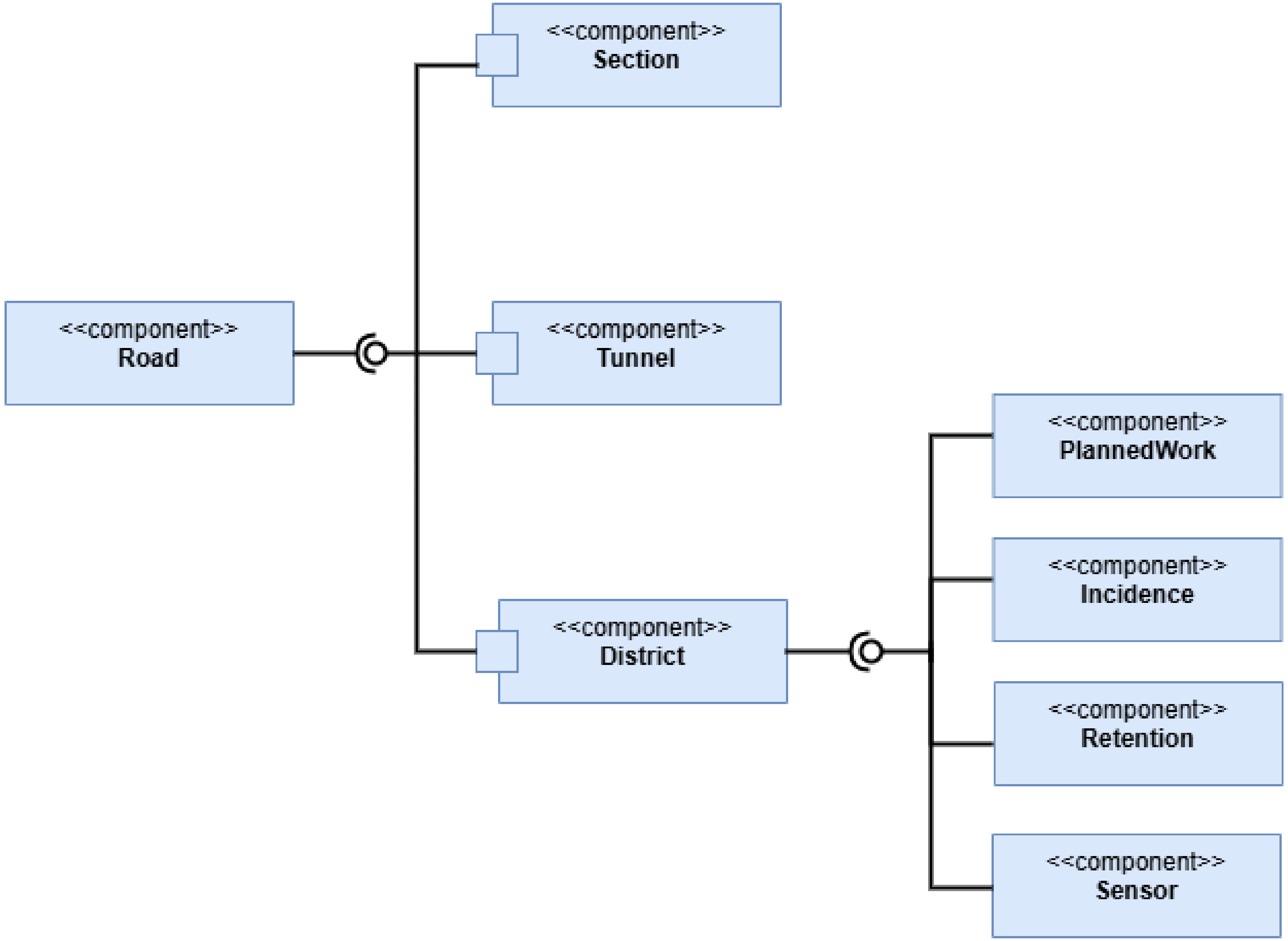
- Modelling and prediction of vehicle traffic.
- Data from Madrid Open Data.
- Updated every 5 minutes.

Goals:

- Improvement of traffic management.
- Reduction of travel time.
- Reduction of accident risks

Case Study: Madrid M-30

Model



Case Study: Madrid M-30

Selecting DT tools

- Although several platforms offer powerful capabilities, not all are suited for this Digital Twin implementations—especially in real-time, IoT-rich environments.
- Some tools are specialized for design/simulation only, lacking real-time integration.
- Others focus on enterprise IT systems, not physical connectivity.
- A few may be powerful but are too complex or costly for this use case.
- Evaluation criteria used:
  - IoT scalability and real-time capabilities
  - Integration with cloud and data platforms
  - Customizability and openness
  - Total cost of ownership
  - Learning curve and deployment complexity

Case Study: Madrid M-30

Selecting DT tools

Platform	Limitations	Selection Rationale
Azure Digital Twins	Pay-as-you-go pricing can become expensive Requires tight integration with Azure services	✅ Excellent integration with IoT, Machine Learning, and 3D visualization ✅ Mature and scalable for industrial use cases
AWS IoT TwinMaker	Pay-as-you-go pricing can become expensive Requires tight integration with AWS services	✅ Supports large-scale IoT deployments ✅ Flexible data sources and 3D visualization
Eclipse Ditto	Requires manual deployment Limited native visualization	✅ Open-source and fully customizable ✅ High interoperability

Case Study: Madrid M–30

Selecting DT tools

Platform	Limitations	Selection Rationale
Siemens Digital Twin	Focused on design/simulation, not real-time IoT Very expensive licensing	❌ Limited for real-time, distributed IoT environments
Oracle Digital Twins	Weak interoperability with external IoT platforms Focused on enterprise asset workflows	❌ Designed mainly for ERP and asset management ❌ Less suited for physical, real-time systems
PTC ThingWorx	No strong native support for real-time sensor updates.	❌ Excellent AR integration but lacks on real-time IoT features ❌ Modular pricing can become costly

Case Study: Madrid M-30

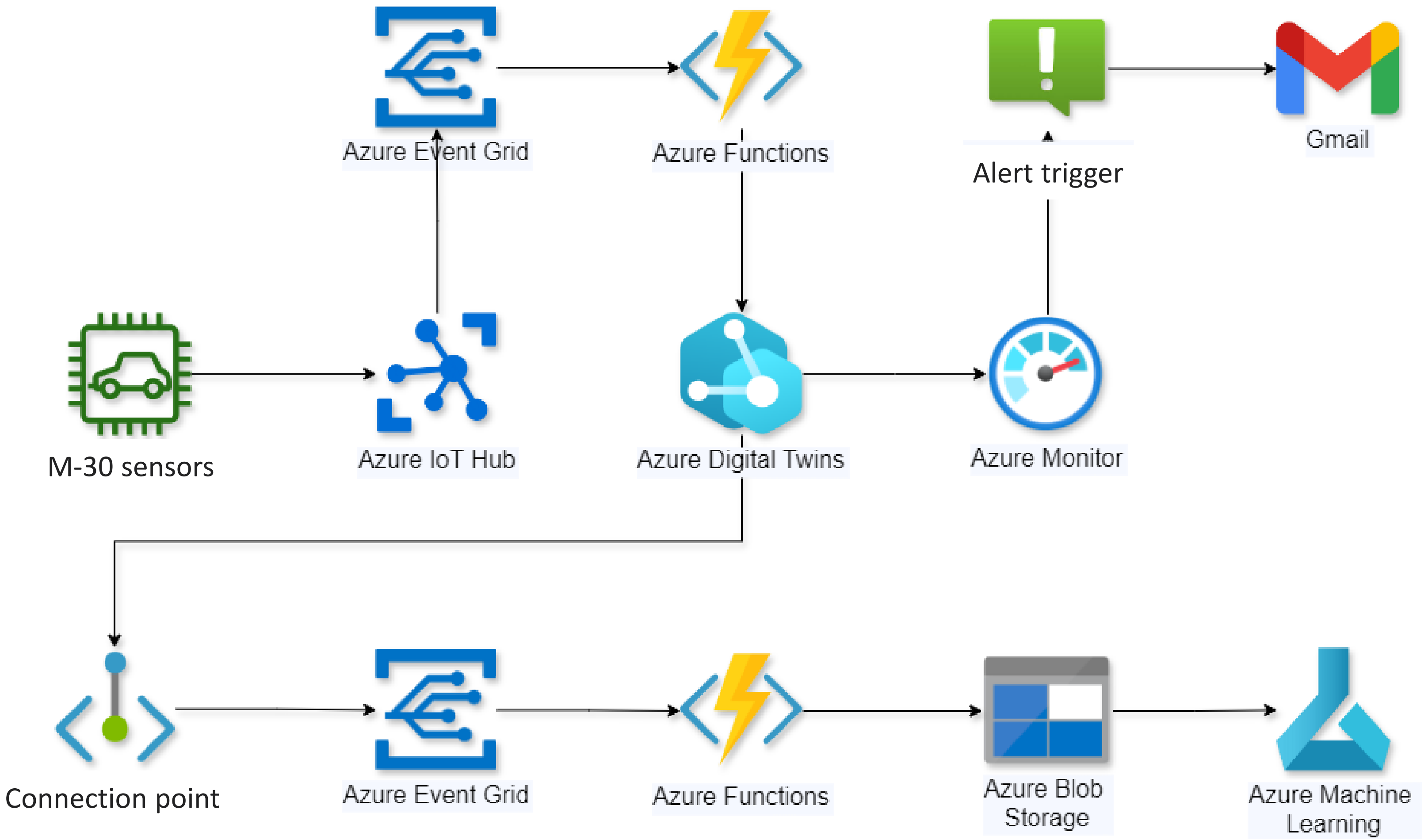
Comparison and evaluation between:

ditto

AWS IoT TwinMaker

Case Study: Madrid M-30

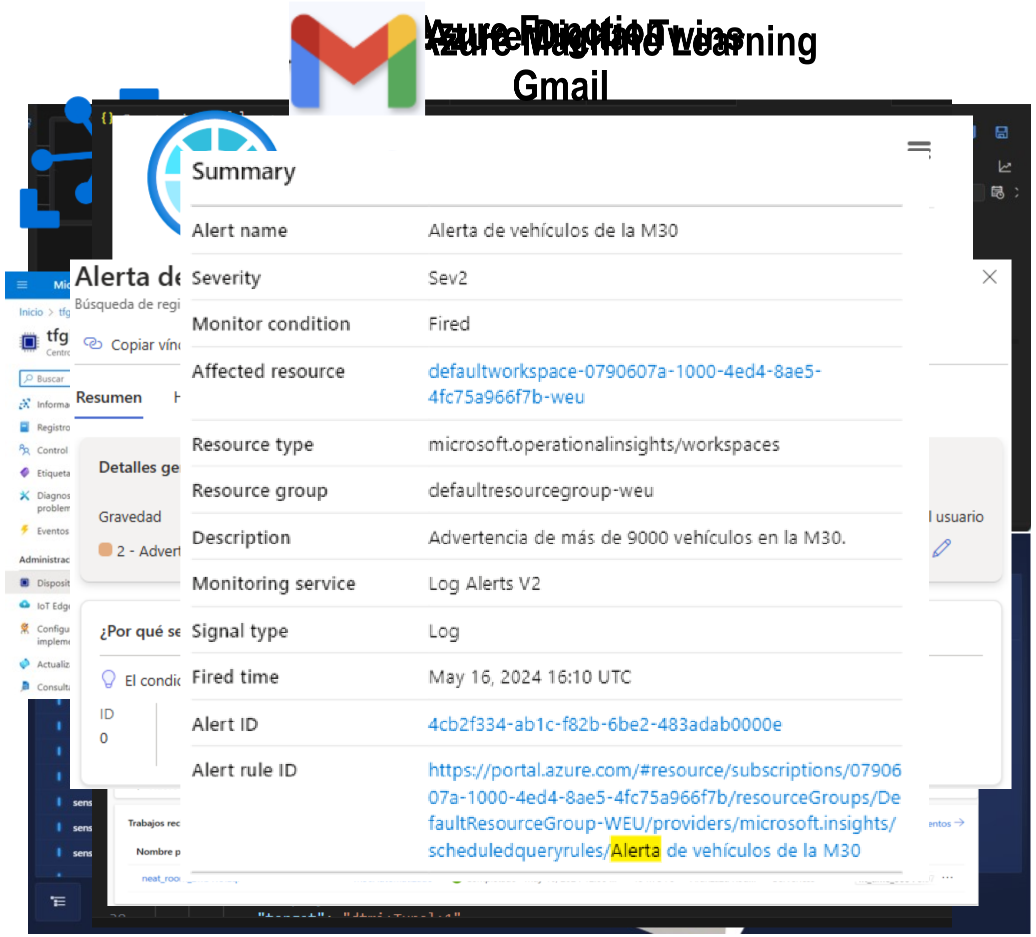
Architecture: Azure Digital Twins



Case Study: Madrid M-30

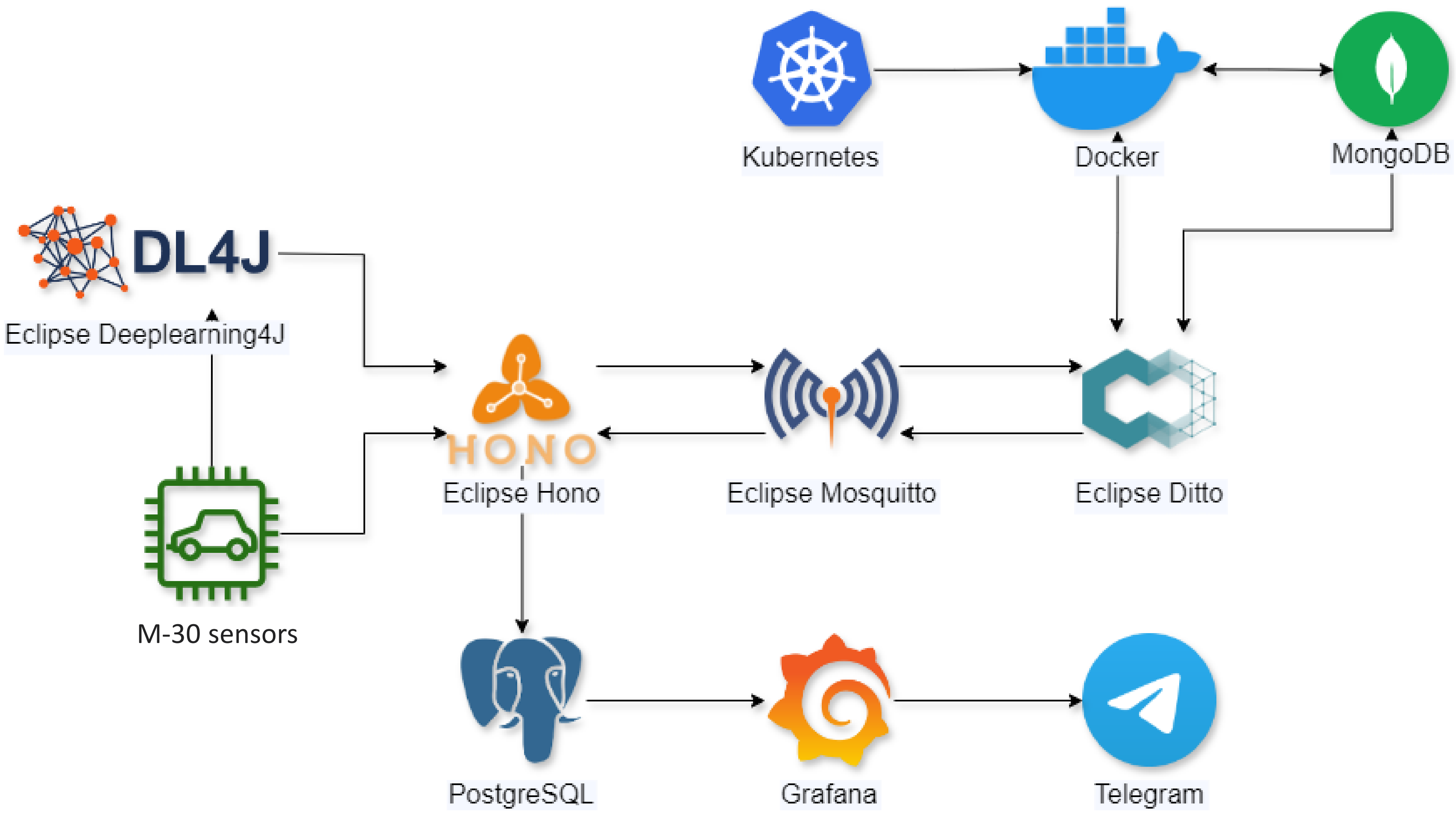
Architecture: Azure Digital Twins

1. IoT device management
2. Event processing
3. Modelling and simulation
4. 3D modelling
5. Machine Learning
6. Alert generation



Case Study: Madrid M-30

Architecture: Eclipse Ditto



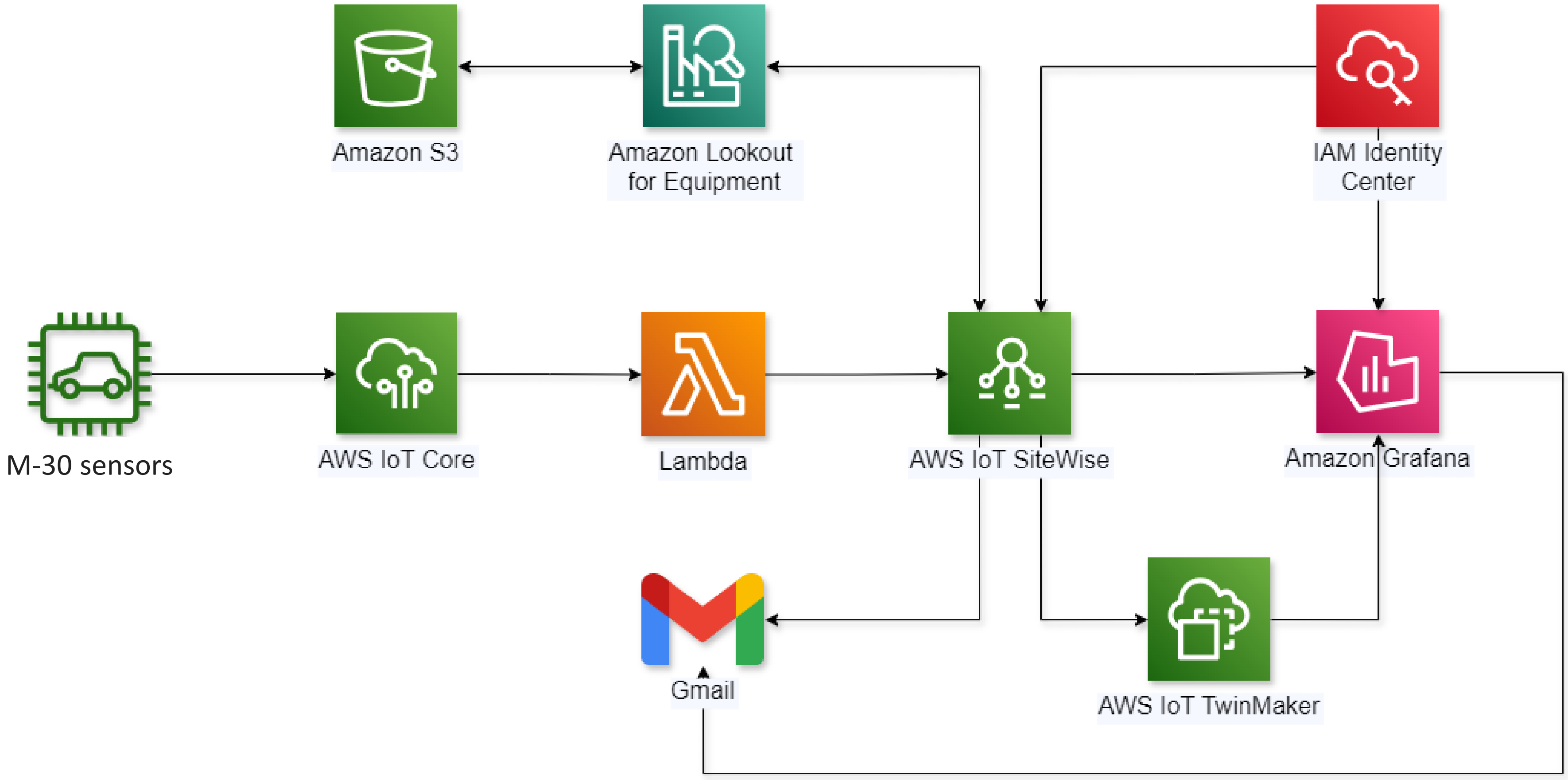
Case Study: Madrid M-30

Architecture: Eclipse Ditto

1. IoT device management
2. Event processing
3. Modelling
4. Machine Learning
5. Alert generation

Case Study: Madrid M-30

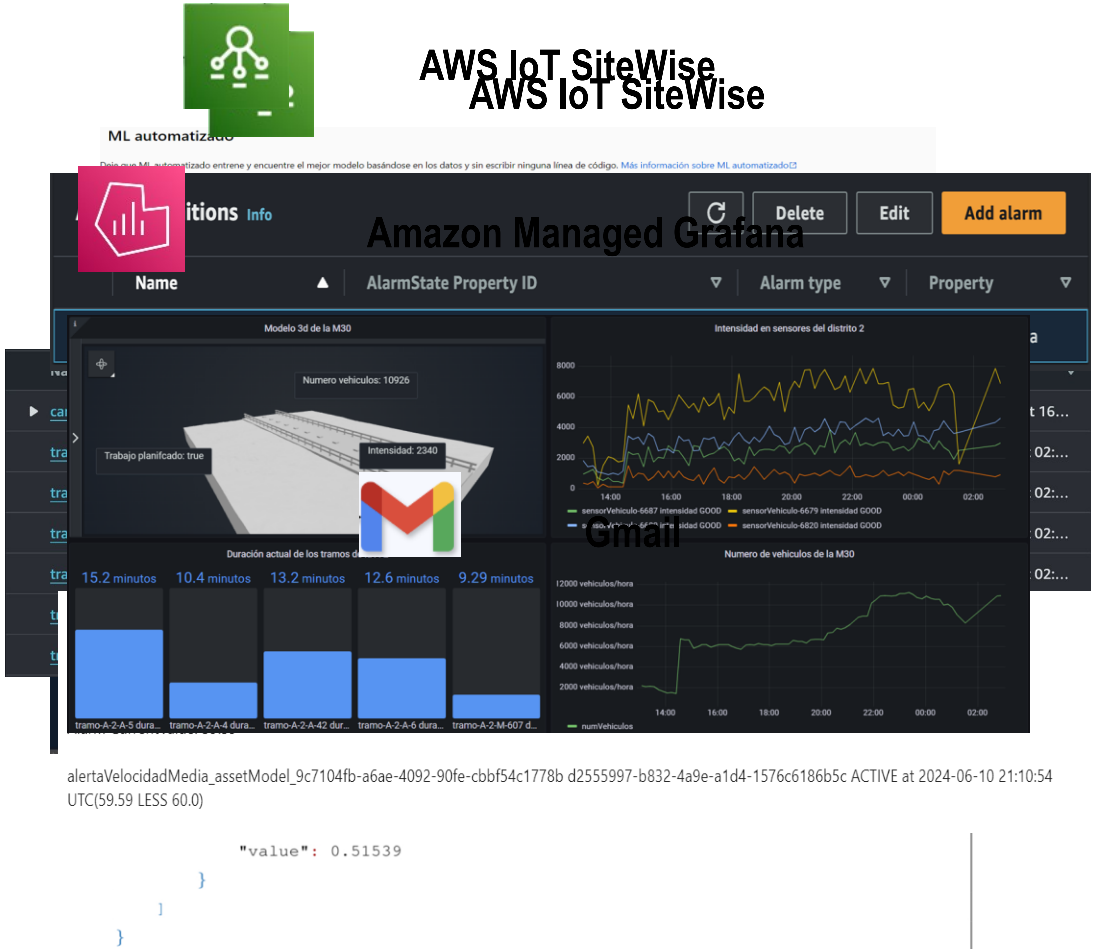
Architecture: AWS IoT TwinMaker



Case Study: Madrid M-30

Architecture: AWS IoT TwinMaker

1. IoT device management
2. Data collection
3. Modelling and simulation
4. 3D modelling
5. Machine Learning
6. Alert generation



Case Study: Madrid M-30

Comparative

Characteristic	Azure Digital Twins	Eclipse Ditto	AWS IoT TwinMaker
Provider	Microsoft	Eclipse	AWS
Support and Documentation	Extensive Microsoft support	Limited but active community	Extensive AWS support
Subscription	✓	✗	✓
Price	33.16€	0€*	9.01€
Development time	130 h	75 h	50 h
Installation	✗	✓	✗
Additional Software	✗	Docker, Kubernetes	✗

Case Study: Madrid M-30

Comparative

Characteristic	Azure Digital Twins	Eclipse Ditto	AWS IoT TwinMaker
Geographical availability	Azure regions	Based on the implementation	AWS regions
Open source	✗	✓	✗
Flexible modelling of Thing	✗	✓	✗
Scalability	✓	✓	✓
Integration with other systems	✗	✓	✗

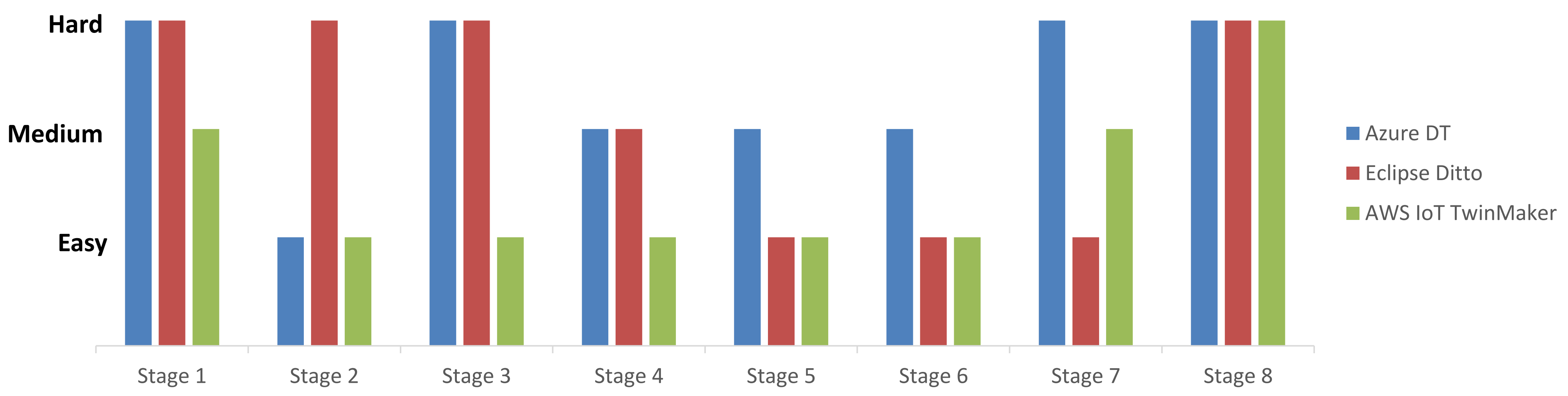
Case Study: Madrid M–30

Summary

Functionality	Azure Digital Twins	Eclipse Ditto	AWS IoT TwinMaker
IoT device management	Azure IoT Hub	Eclipse Hono	AWS IoT Core
Event procesing	Azure Functions	Eclipse Mosquitto	AWS Lambda
3D modelling and visualization	Azure DT - 3D Scenes	Unity*	AWS IoT Twinmaker
Machine Learning	Azure Machine Learning	Deeplearning4J	Amazon Lookout for Equipment / Sagemaker
Alert generation	Azure Monitor	Grafana	AWS Grafana, AWS SiteWise

Case Study: Madrid M-30

Learning Curve

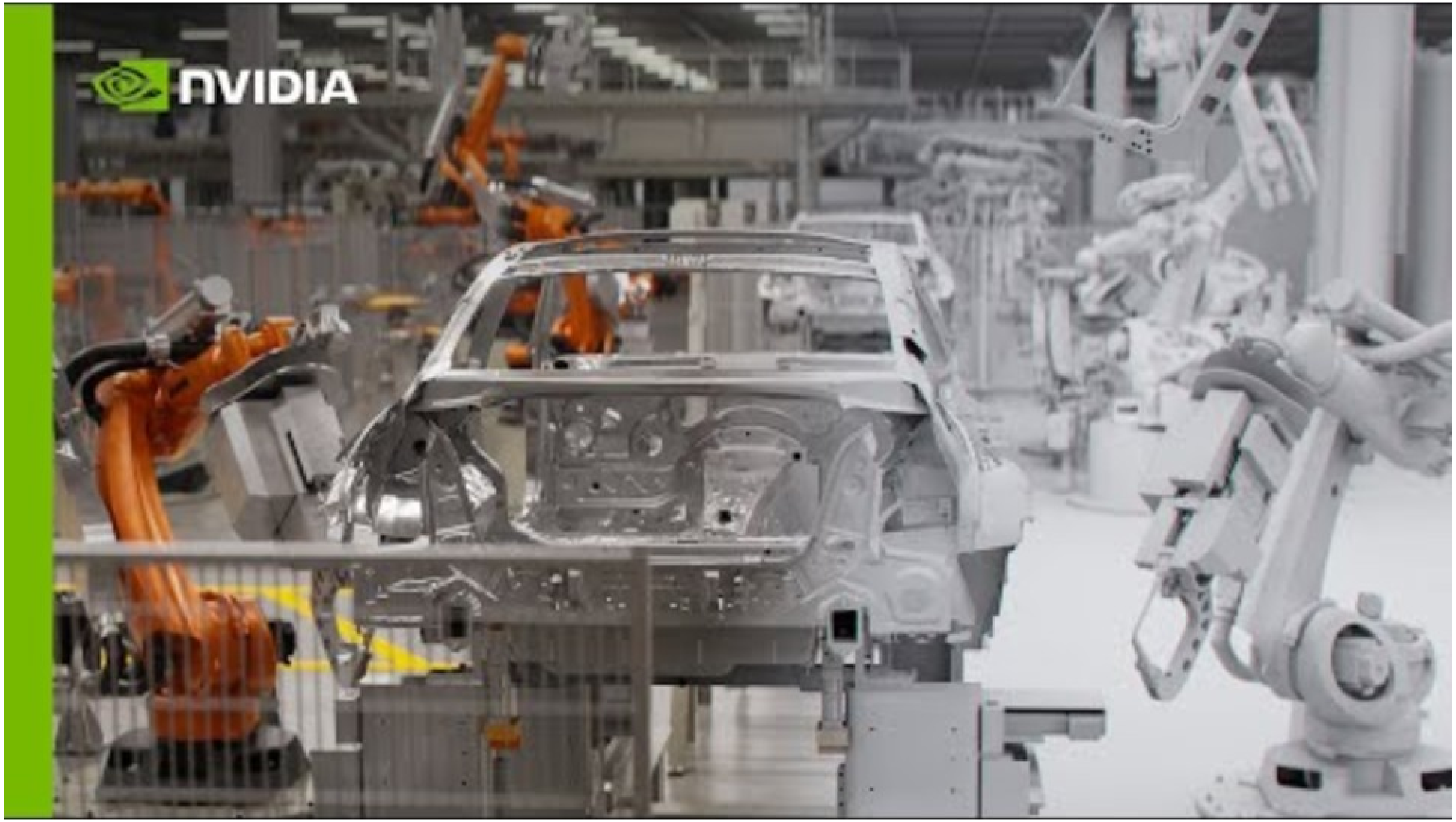


- **Stage 1**: Identification of services
- **Stage 2**: Installation or subscription
- **Stage 3**: IoT device management
- **Stage 4**: Modeling of Thing
- **Stage 5**: Model generation
- **Stage 6**: Data visualization
- **Stage 7**: Alert generation
- **Stage 8**: Predictions

4. More use cases

Use cases

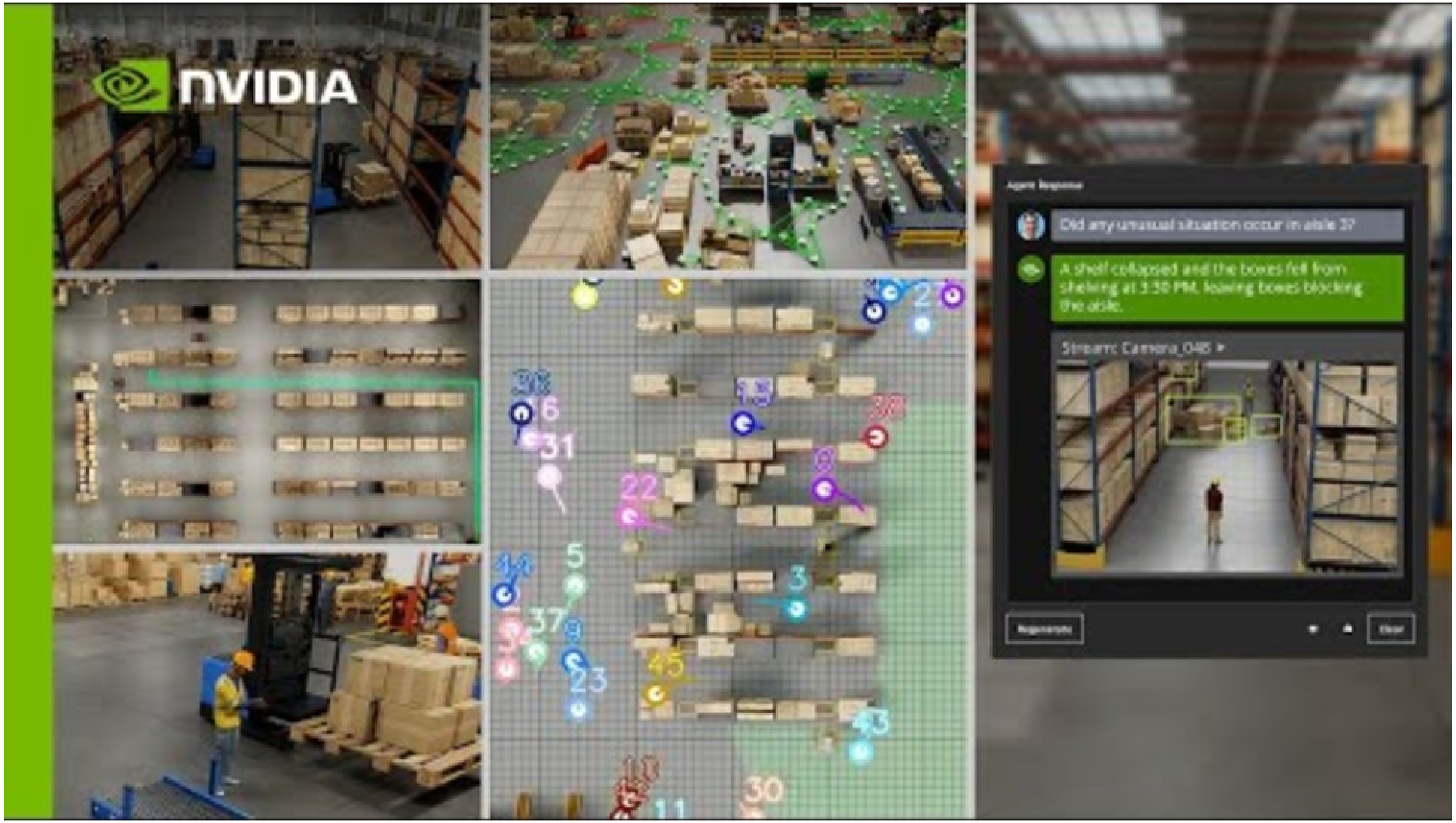
BMW – iFactory



[This is how DIGITAL the BMW iFACTORY is.]

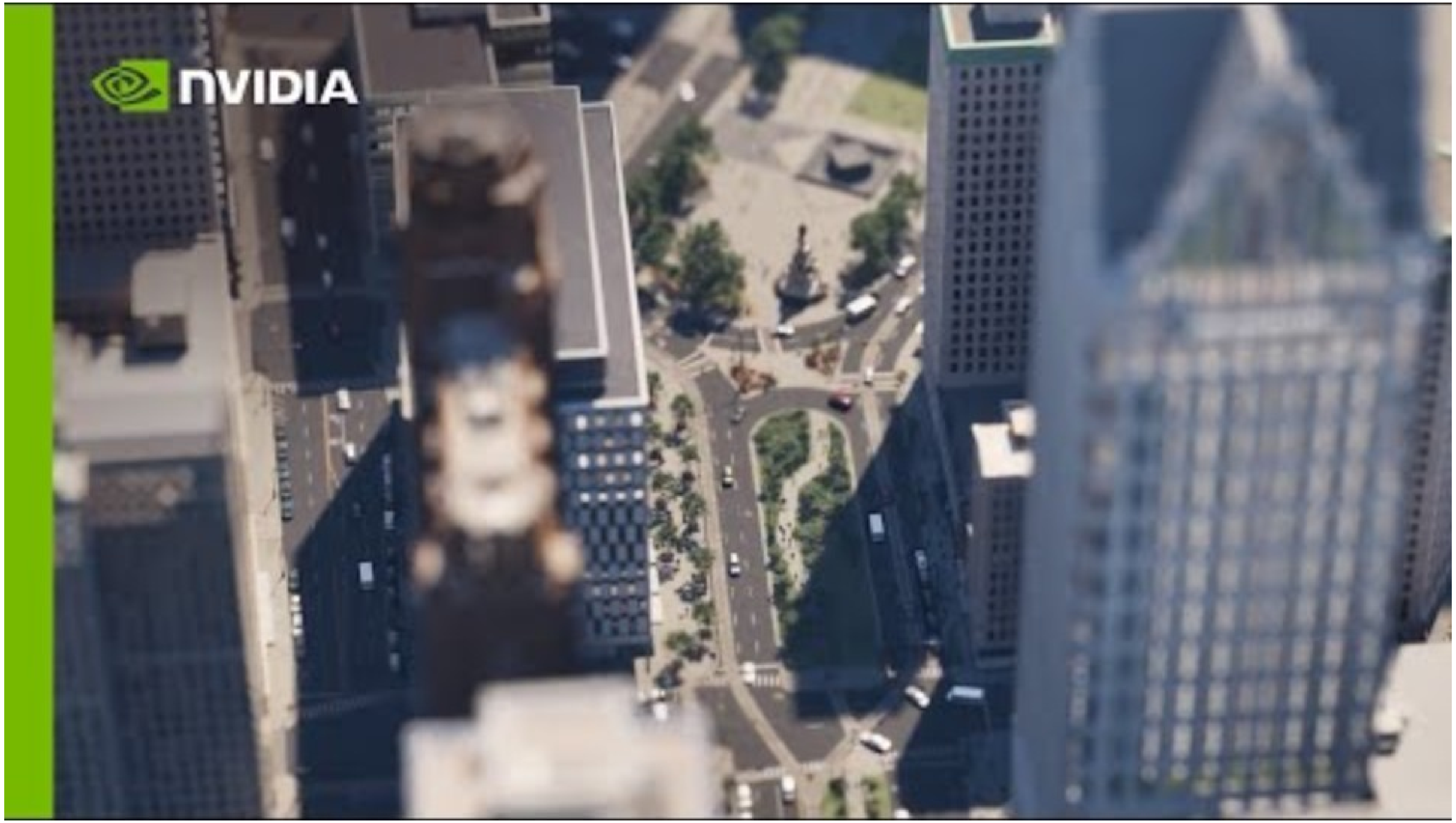
Use cases

NVIDIA – Digital Twins With Real-Time AI for Industrial Automation



Use cases

NVIDIA – Omniverse Blueprint



is not an
Nvidia promo :D

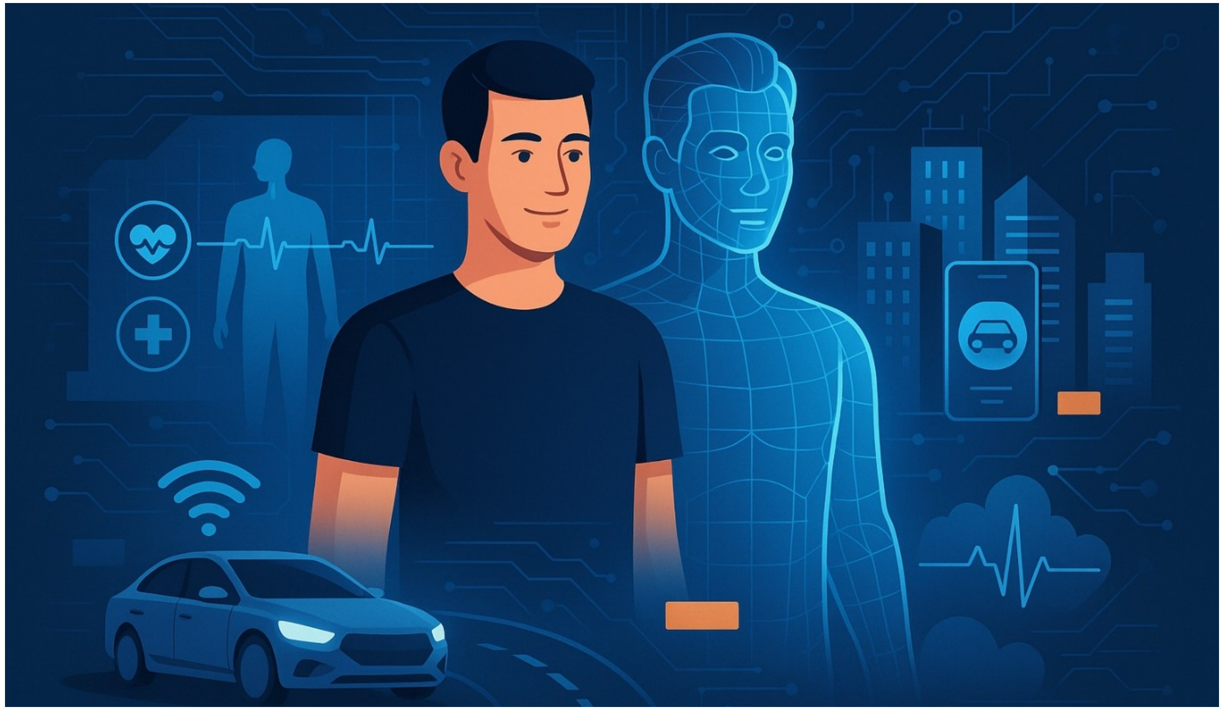
5. New trends

New trends

Human Digital Twins

- Why?
  - Key value of Industry 5.0, smart cities or smart vehicles
  - Collaboration and integration with machines and technologies

- Challenges:
  - Architectures
  - Integration
  - Interoperability
  - Privacy & Security



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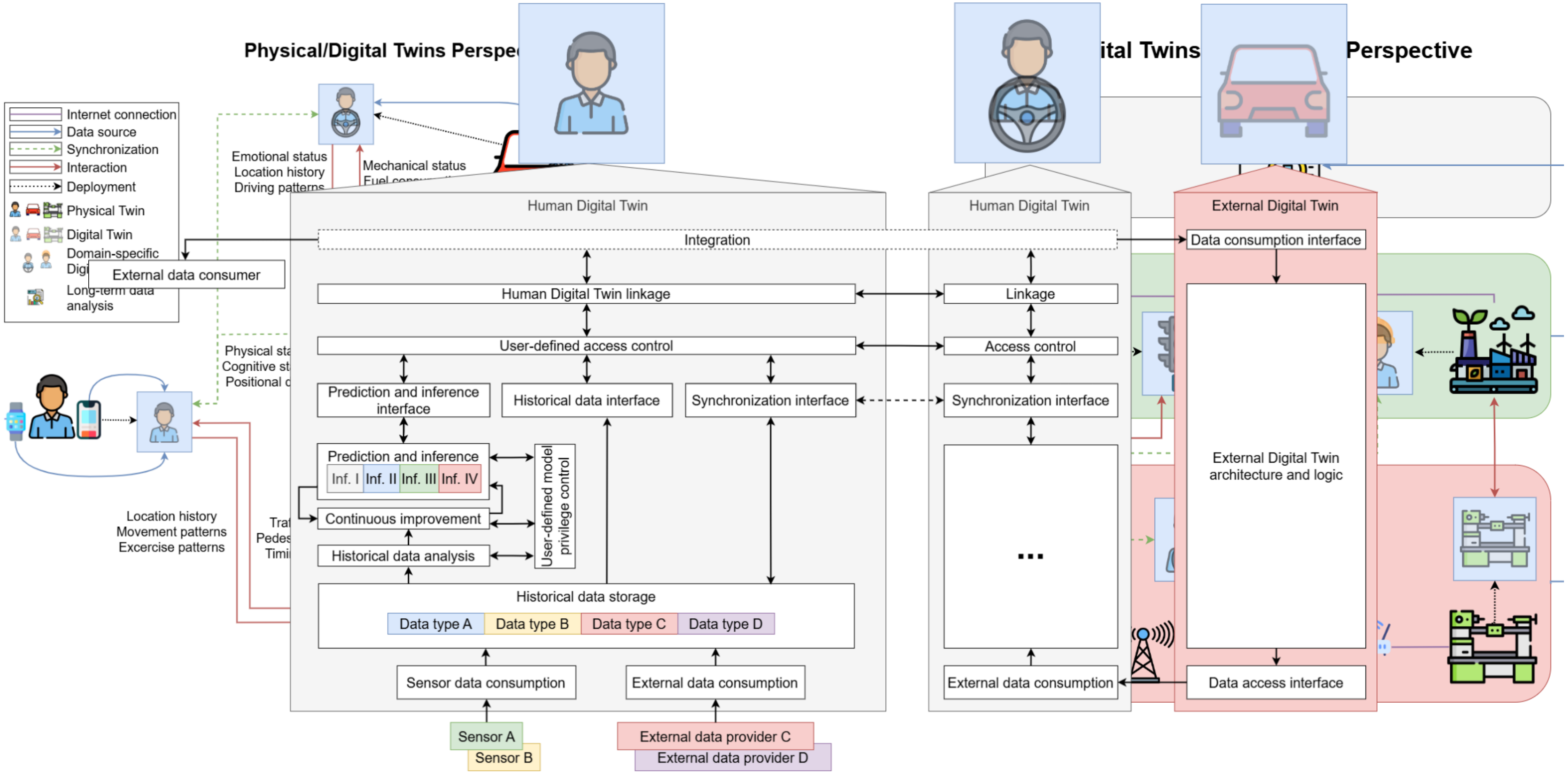
Wang, Baicun, et al. **Human Digital Twin in the context of Industry 5.0**. Robotics and Computer-Integrated Manufacturing, 2024

New trends

Human Digital Twins

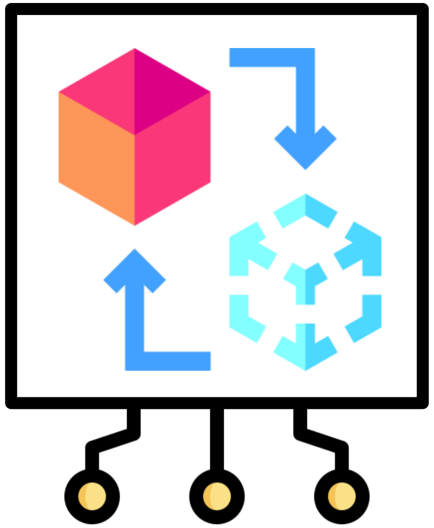


Laso, Sergio, et al. **Human Digital Twins: Enhancing Interactions with Digital Ecosystems**. *IEEE Internet Computing*, 2025.

New trends

Digital Twin-as-a-Service (DTaaS)

- Why?
  - Companies won't need to build their own twins — they'll subscribe to them like cloud services.
  - Helpful for startups, SMEs, or businesses without IT teams to launch digital twins quickly.
- Challenges:
  - Integration
  - Interoperability
  - Privacy & Security
  - Vendor Lock-in



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Chen, Zijue, et al. **Service oriented digital twin for additive manufacturing process.** Journal of Manufacturing Systems, 2024.

6. Conclusions

Conclusions

- Digital Twins are powerful enablers for predictive analytics, optimization, and real-time decision-making across industries.
- Among many available platforms, stand out due to:
  - Strong real-time IoT integration
  - Flexibility and scalability
  - Clear architectural patterns and deployment options
- Despite the growing body of use cases, practical implementation is still challenging due to:
  - Lack of sensorization in real-world environments
  - Fragmented tool ecosystem and lack of standards and interoperability
  - High technical and financial barriers

Thanks!

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