THE CONCEPT OF A DIGITAL TWIN BASED ON THE ASSET ADMINISTRATION SHELL (AAS) STANDARD WITH 3D VISUALIZATION

ANASTASIIA NAZIM[1], KAMIL ZIDEK[1], MICHAL DUHANCIK[1]

[1]Technical University of Kosice, Faculty of Manufacturing Technologies with the seat in Presov, Bayerova 1, 080 01 Presov, Slovakia

DOI: 10.17973/MMSJ.2025_09_2025083

anastasiia.nazim@tuke.sk

The paper presents the integration of digital twins into industrial processes using the Asset Administration Shell (AAS) standard. The research describes the basic concept of implementing the AAS standard for industrial data collection from selected automation devices. The core component of data collection is the AAS server, which serves as a bridge between the real process and data visualization. Real devices synchronize data with the AAS server via an OPC server. Digital twin representations in AAS virtual devices provide data through REST API communication. The visualization of digital twin data from selected devices is demonstrated using an Unreal Engine application. This application offers a wireless connection to the XR device Meta Quest 3 for enhanced interaction with virtual objects.

KEYWORDS

Digital twin, Asset Administration Shell, Control Systems, Cross Reality

1 INTRODUCTION

The digital revolution is driving a fundamental change in manufacturing, pushing industries towards smarter, more interconnected, and self-governing systems. This transformation, known as Industry 4.0, centers on embedding cyber-physical systems (CPS), the Internet of Things (IoT), cloud computing, and real-time data analysis into established industrial settings [Khan 2022]. Digital Twin is a key technology driving this transformation, offering a dynamic, up-to-the-minute virtual model of physical objects, systems, and operational procedures.

A Digital Twin acts as a two-way link, seamlessly connecting the physical and digital realms. It constantly gathers data from sensors, actuators, and control systems within the physical world, mirroring these updates in its virtual representation. This ongoing synchronization empowers stakeholders to observe, simulate, troubleshoot, and enhance industrial processes in real time. Digital twins are employed across a wide range of applications, such as predicting maintenance needs, enabling remote diagnostics, optimizing production planning, training workers, and conducting safety evaluations [Tao 2018], [Yoon 2023]. As industries shift from fixed, predetermined systems to flexible, adaptable production setups, digital twins empower enhanced agility, responsiveness, and robustness [Stark 2019].

However, the creation of an effective and scalable digital twin system depends significantly on standardization of data models, interfaces, and communication protocols. Without a common digital representation of assets, interoperability between different systems, devices, and vendors becomes a major challenge [Liu 2025]. This is where the Asset Administration Shell (AAS) comes into play.

The AAS, defined by the IEC 63278 standard and aligned with the Reference Architecture Model for Industry 4.0 (RAMI 4.0), provides a structured, semantic, and machine-interpretable digital representation of an industrial asset [Evans 2022]. It acts as a digital envelope or “shell” that encapsulates all relevant information about a physical or logical asset, including its identity, technical specifications, operational parameters, lifecycle documentation, and offered services. The AAS facilitates interaction through submodels—modular blocks of information—making it adaptable to a wide range of use cases and industries [Huang 2021b].

One of the key strengths of the AAS is its compatibility with modern industrial protocols such as OPC UA, MQTT, JSON, and RESTful APIs, enabling seamless communication across heterogeneous systems [Huang 2021a]. It also supports integration with various IT and OT platforms, including MES (Manufacturing Execution Systems), ERP (Enterprise Resource Planning), PLM (Product Lifecycle Management), and cloud services. The AAS essentially provides the semantic backbone for digital twins, ensuring data consistency, traceability, and interoperability across the industrial value chain [Zhang 2025].

Despite the technical maturity and growing adoption of the AAS framework, a significant limitation remains in its integration with immersive visualization platforms, such as 3D graphics engines and Extended Reality (XR) interfaces [Huang 2021a]. While AAS efficiently manages data and services, it lacks native support for spatial visualization, user interaction, or simulation capabilities. These elements are increasingly vital in Industry 5.0, which emphasizes human-centric design, intuitive interaction, and collaboration between humans and machines.

3D visualization and XR technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), dramatically enhance the effectiveness of digital twins by providing immersive, interactive, context-rich environments. Through these technologies, users can interact with complex machines, monitor live sensor data, simulate process changes, and visualize maintenance tasks in a spatial and intuitive manner. This approach improves operational awareness, shortens training cycles, and enhances safety and efficiency [Kim 2023], [Nguyen 2024], [Salama 2024].

However, bridging the gap between structured industrial data (AAS) and visual representation (XR) presents several challenges. These include synchronization of real-time data flows, mapping abstract digital models into 3D geometries, network latency, device compatibility, and the complexity of developing maintainable integration pipelines. Most existing research focuses on either the data model (AAS) or the visualization layer (XR), but not on their seamless integration in a unified framework.

This paper aims to address this research and implementation gap by proposing and evaluating a method for integrating the Asset Administration Shell standard with 3D visualization in Unreal Engine and wireless XR devices such as Meta Quest 3. Our contribution includes the design and deployment of an architecture that links industrial devices (e.g., robots, sensors) to an AAS server via OPC UA, retrieves real-time data through REST APIs, and visualizes this data in Unreal Engine for immersive XR-based interaction.

2 DIGITAL TWIN IN INDUSTRY

A digital twin is a virtual representation of a physical object, system, or process. It serves as a real-time digital counterpart that mirrors the characteristics, behaviors, and performance of the physical entity [Liu 2025]. Digital twins are created using data generated by the physical object through sensors, IoT devices, and other data collection methods.

They are commonly used in various industries such as manufacturing, healthcare, and smart cities for purposes such as monitoring performance, simulating scenarios, optimizing operations, and predicting maintenance needs.

2.1 Digital Twin Standards

Digital twins are a key technology in the development of Industry 4.0, as they enable the integration of physical objects with digital management systems. There are several international standards for creating digital twins, the most common of which are Asset Administration Shell (AAS), OPC UA (Open Platform Communications Unified Architecture), ISO 23247 (Digital Twin Framework for Manufacturing), ISO 21838 (Top-Level Ontologies).

Standard	Year	Application	Supported Technologies	Advantages
AAS	2015	Industry 4.0, industrial assets	IEC 63278, OPC UA, JSON, XML	Deep integration into industry, standardizatio n
ISO 23247	2020	Manufacturing and product lifecycle management	ISO standards for industrial systems	Clear structure for manufacturin g, ISO support
ISO 21838	2021	Harmonization of ontologies for digital twins	Ontologies, semantic models	Compatibility between standards and scientific support

Table 1. Key digital twin standards: application, technologies, and benefits

AAS is a framework that describes an asset (e.g. machine, component, software) and provides all relevant information about it in digital form. This standard is being developed by the Plattform Industrie 4.0 community and is described in a series of specifications such as IEC 63278 (formerly known as DIN SPEC 91345) [Evans 2022]. The Asset Administration Shell (AAS) standard enables the integration of digital twins into industrial environments. As a standardized digital representation of physical assets, AAS enables seamless communication between real components and their virtual counterparts. It structures data in submodels that reflect the asset's identification, technical specifications, operational status, and related documentation [Huang 2021a]. These submodels can be updated in real time using industrial communication protocols such as OPC UA. In a typical integration process, a physical asset (e.g. machine, robot, or sensor) sends data via an OPC UA server to an AAS server, which then encapsulates this data in the appropriate submodels [Schmitt 2019]. The AAS server exposes this data via REST API, allowing external applications such as 3D visualization platforms (e.g. Unreal Engine) to access it dynamically.

Compared to other frameworks such as ISO 23247 and ISO 21838, AAS provides higher deployment maturity, strong tool support (e.g. Eclipse BaSyx), and better compatibility with existing industrial infrastructure. The ISO 23247 standard was first mentioned in 2020. It aims to provide a structured model for the digital twin in manufacturing processes [Melo 2024]. Its goal is to create a consistent approach to the digital representation of physical objects, processes and resources based on observable manufacturing elements (OME). The standard covers the principles of data collection, processing and synchronization between the physical and digital environments to ensure the reliability, integration and interoperability of digital twins in industrial applications [Minh 2024].

Another standard, ISO 21838, introduced in 2021, is an international standard that defines general requirements for ontologies used for the exchange, integration and coordination of knowledge within complex digital systems [Drobnjakovic 2023]. This ensures interoperability between different standards and systems, which contributes to data unification. However, its high abstraction and difficulty in adapting to real-world industrial environments limit its widespread use.

Comparing the standards for creating a digital twin, the Asset Administration Shell (AAS) is the most efficient and adaptable for use in industry, providing reliable integration and communication between production and its digital copy.

One of the key advantages of AAS is its integration with all the principles of Industry 4.0, as it was specifically designed to support industrial digitalization. The inclusion of the IEC 63278 standard ensures compliance with internationally recognized standards, facilitating its widespread use in various industries. In addition, its support for OPC UA, JSON and XML provides flexible data exchange, making it adaptable to different system architectures and existing infrastructures.

Compared to other approaches such as ISO 23247, which, although offers a conceptual framework for modeling digital twins in a manufacturing environment, remains relatively new and has limited adoption in industry. It lacks mature implementations and standardized cybersecurity infrastructure, which makes its practical application difficult.

Another standard, ISO 21838, focuses on unifying ontologies to ensure semantic compatibility between different digital twins. Despite its important role in harmonizing conceptual models, its high abstraction and resource requirements make it difficult to implement in real-world production environments. AAS has received significant support from government agencies, research institutions, and industry alliances, which has led to a growing number of projects and software tools supporting it. This support confirms its long-term viability and dominance in the digital twin space. By clearly structuring information through submodels, AAS provides consistent data management, high accuracy, and traceability, which is critical for industries with increased quality and safety requirements.

2.2 Related works

The Role of Asset Administration Shell (AAS) in Industry 4.0 and Digital Twin Technologies

The Asset Administration Shell (AAS) is emerging as a key standard for implementing digital twins in Industry 4.0 environments, providing structured digital representations of physical assets and enabling interoperability across cyber-physical systems [Negri 2023]. AAS addresses semantic and syntactic interoperability challenges, supporting capability-based operations and flexible production lines [Huang 2021b]. By integrating Functional Mockup Units (FMUs), AAS facilitates cloud-based simulation platforms that enhance system-level integration, verification, and optimization across different lifecycle phases [Juhlin 2022]. Digital twins are becoming central to Industry 4.0, enabling smart assembly processes and resilient manufacturing systems. AAS has been identified as a crucial model for developing digital twins, particularly in facilitating higher-order transformations for improved interoperability [Ferko 2024]. A structured approach for implementing AAS-based digital twins in complex production environments has been proposed, focusing on the identification and characterization of asset types and their interrelationships [Gartner 2022]. This structured approach enhances scalability, automation, and data-driven decision-making. Furthermore, digital twins based on AAS have been applied to industrial 5G systems, demonstrating their potential in enhancing system resilience and optimizing networked manufacturing environments [Cainelli 2021]. Studies have also explored the convergence of AAS and digital twin models, proposing merged frameworks that ensure seamless physical-virtual data interaction [Ye 2023].

Also, AAS serves as the backbone for smart manufacturing services, allowing for automated asset management and standardized communication between industrial components [Park 2021]. Researchers have extended AAS to incorporate human characterization, enabling human-centered control in factory digital twins [Cutrona 2023]. This extension aligns with Industry 5.0, where human factors play a crucial role in optimizing manufacturing processes. In construction, AAS-based digital twins have been used for automating precast concrete production, streamlining series manufacturing processes [Kosse 2022]. To further enhance AAS interoperability, researchers have introduced ontology-based models, which transform AAS-based plant models into ontology instances, allowing for more flexible resource matching and data exchange [Huang 2023]. These ontology-driven approaches improve semantic expressiveness, making AAS more adaptable to diverse industrial applications [Rongen 2023].

Despite advancements, current AAS implementations face key challenges. Issues such as high response times, lack of standardized deployment frameworks, and limited interoperability with existing industrial systems hinder widespread adoption [Evans 2022]. To address these challenges, event-based AAS servers have been proposed to improve real-time data processing, along with multi-agent systems for automated AAS deployment [Evans 2022]. Additionally, cloud-enabled AAS architectures have been introduced to facilitate real-time collaboration and predictive maintenance [Juhlin 2022].

Emerging research suggests that AAS, digital twins, and data space technologies (e.g., Gaia-X, IDS) can be integrated to enhance value chain optimization and manufacturing resilience [Bakopoulos 2024]. However, achieving full interoperability and standardization remains a challenge. While European standardization efforts [Zezulka 2022] provide recommendations for AAS implementation, further work is needed to harmonize AAS models across different industrial sectors [Zezulka 2022].

The Asset Administration Shell (AAS) and digital twins are revolutionizing smart manufacturing by enabling interoperability, automation, and real-time decision-making. Their integration with cloud computing, ontology-based models, and human characterization frameworks is paving the way for more flexible, resilient, and intelligent production systems. While significant progress has been made, further research is needed to address interoperability gaps, enhance real-time data exchange, and standardize AAS implementations to fully realize the potential of Industry 4.0 and 5.0.

2.3 AASX Package File Format

AASX is a file format (container) intended for storing and exchanging digital twins of the Asset Administration Shell (AAS) type within the Industry 4.0 environment.

A single AASX file can contain:

1. Metadata and structured information about the given entity (the AAS model),
2. Submodels that describe individual parts or properties of the entity in detail,
3. Attachments, resources, and documents (such as technical drawings, manuals, or certificates).

In this way, AASX acts as a comprehensive package of all digital information about the relevant object, which simplifies data exchange between various information systems and IoT platforms. It also provides a unified format ensuring interoperability in the context of Industry 4.0. The AAS submodels are divided into four groups:

- Identification
- Technical Data
- Operational Data
- Documentation

Identification data consists of unique data for example: serial number, manufacturer, etc.

Technical data consists of fixed maximum performance of current devices, for example: speed, load, torque, etc.

Operation data is actual data of device in working status for example actual speed, position, acceleration, etc. This data must be actualized in time as dynamic values.

Documentation data can contain external hyperlinks or local files, for example manuals or 3D models and can be part of AASX file.

Fig. 1 illustrates the four key types of submodels used to describe an asset: Identification, Technical Data, Operational Data, and Documentation. For example, the Identification submodel includes metadata such as the manufacturer's name, Global Location Number (GLN), product designation, and serial number. The Technical Data submodel contains fixed characteristics like maximum rotation speed, torque, or cooling type. The Operational Data submodel is designed to reflect real-time values during the asset's functioning, such as current rotation speed or torque. Finally, the Documentation submodel provides links to external resources like operating manuals or 3D models, ensuring easier access to supplementary materials.

Figure 1. AAS device consists of 4 basic data submodel types

2.4 AAS User Interface

BaSyx is an open-source software platform, which focuses on supporting Industry 4.0 concepts, primarily for creating digital twins of the Asset Administration Shell (AAS) type. The primary objective of the BaSyx platform is to simplify the integration of various industrial devices, production lines, and IT systems through standardized interfaces and data management tools. BaSyx features a modular architecture composed of multiple intercompatible components, allowing it to be adapted to specific industrial requirements. The platform actively implements and promotes open industrial standards, thereby enabling a high level of compatibility and easy data exchange between different systems. Thanks to its open-source nature, the system can be extended with custom add-ons.

In industrial practice, Eclipse BaSyx is used for

- Monitoring and controlling machines or equipment,
- Collecting, processing, and analyzing production data, Integrating with cloud services or other information systems,
- Building a comprehensive IoT infrastructure in factory or logistics environments.

Key Modules and Components of the BaSyx Ecosystem:

1. AAS Registry (Registration Service)

Provides registration, lookup, and management of available AAS (digital twins) within the network. It contains information on where a particular AAS is accessible and how to connect to it.

2. AAS Server

Responsible for the actual management of individual Asset Administration Shells and provides access to them through defined interfaces (REST API, OPC UA, MQTT, etc.). It may also include basic logic for handling submodels and their data entities.

3. Submodel Repository

Serves as dedicated storage for submodels, i.e., detailed parts or properties of an AAS (such as technical product data or production parameters). It allows reading, creating, and updating submodels according to the specific requirements of a process or application.

4. BaSyx Control Components

Components that facilitate interaction with real-world devices, machines, or production lines. They form a bridge between the digital representation in the form of AAS and the corresponding physical environment (including data collection from actual operations).

5. Security Components

Include mechanisms for authentication, authorization, and secure communication. Their goal is to ensure that AAS and related submodels are handled in compliance with defined access rights.

6. Data Connections and Gateways

Used to connect to various industrial protocols (e.g., OPC UA, MQTT), databases, cloud services, or external systems (ERP, MES, etc.). They enable the creation of data flows between the physical environment (sensors, machines) and the AAS Server or Submodel Repository.

7. SDK and Development Tools

Consolidate libraries, templates, examples, and other resources that simplify the development of custom solutions. They also provide tools that streamline the design and management of digital twins.

3 AAS IMPLEMENTATION

The main part of AAS implementation consists of these steps:

- automation devices selection,
- parametrization of devices,
- parameter registration as AAS standard,
- data synchronization between real devices,
- connection to visualization technology.

3.1 *Selected experimental devices for transformation to AAS digital twin*

We selected for the research concept of AAS DT some SmartTechLine sensors and integrated robots to visualise its parameters:

- SmartTechLab line sensors:
  Temperature, Humidity, CO2, Air pressure for pneumatics systems, Line status.
- ABB IRB 14000:
  Device failure, Operating time, Work cycles, Arm axis X, Y, Z, Robot status.
- SCARA Mitsubishi robot:
  Work cycles, Robot status, Operating time

Real devices selected for transformation to digital twin are shown in Fig. 2.

(a) (b) (c)

Figure 2. SmartTechLab line sensors (a), ABB Collaborative robot (b), SCARA Mitsubishi robot (c)

To manage the digital twins, the Eclipse BaSyx platform was used, which enables the visualization of AAS structures and interaction with the data via a web-based interface. Fig. 3 shows an example of the AAS Viewer interface for a Mitsubishi SCARA robot. Within the interface, the user can select a digital shell (e.g., Mits_SCARA) and browse through its associated submodels. In the Operation Data q submodel, properties such as ON/OFF status and work cycles are visible. The Documentation submodel includes interactive files like a PDF instruction manual, which can be viewed directly within the browser. This functionality provides engineers with immediate access to technical documentation directly from the digital asset shell.

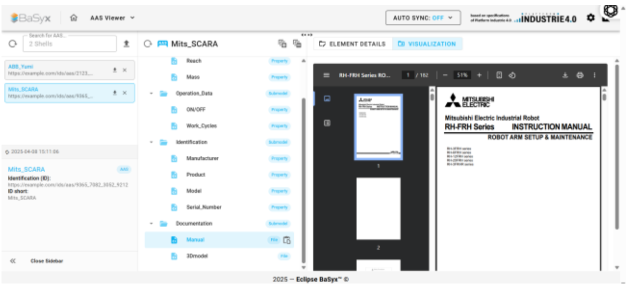

Figure 3. UI for digital twin devices registration to AAS server

In addition to the web interface, AASX Package Explorer was used to edit and validate the AAS files, as shown in Fig. 4. This example displays the structure of the digital twin for the ABB IRB 14000 robot.

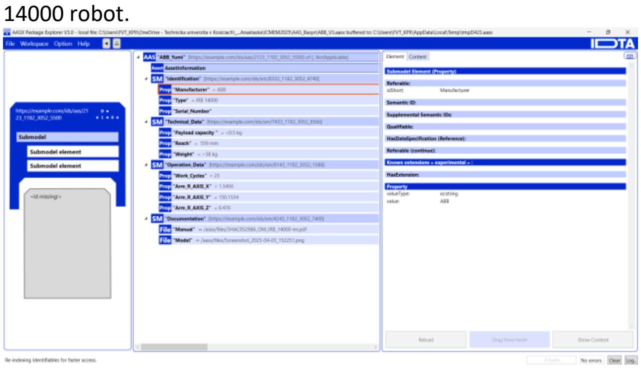

Figure 4. AAS Package Manager to modify AASX files with devices

The interface presents submodels including Identification, Technical Data, Operation Data, and Documentation. Each submodel contains editable properties such as work cycles, joint positions, or document links. The AASX Explorer is an efficient tool for developers, enabling easy management of digital twin data and export to the unified .aasx file format.

4 METHODS OF COMMUNICATION BETWEEN THE REAL SYSTEM AND DIGITAL MODEL

Basic methodology integrates three AAS software packages:

- AAS server
- AAS web UI
- AAS Manager

AAS web UI provides a simple interface for devices data types of registration in standardized AAS structure to AAS server. The AAS server runs in loop and provides access to device parameters by REST API interface. AAS manager is an external application for check consistency of AASX files, which can be exported as backup file in aasx format.
The basic methodology of dataflow between DT based on AAS and XR devices is shown in Fig. 5.

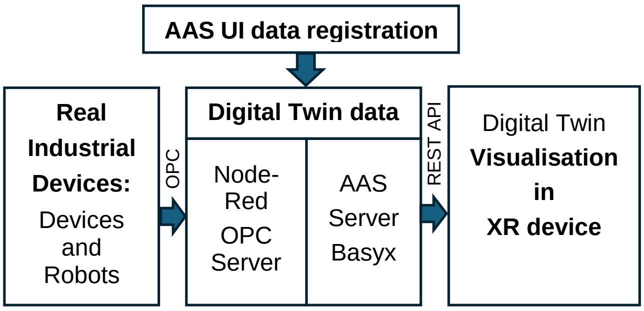

Figure 5. Basic methodology dataflow between digital twin and XR visualization

OPC-UA creates basic bridge between real process and synchronies data between AAS sever.
REST-API is a basic communication interface for AAS server and provides synchronization to visualization by XR devices.

5 VISUALIZATION

In the context of digital twin visualization, immersive technologies such as Extended Reality (XR) offer significant benefits by enabling users to interact with digital models in real-time, spatially accurate environments. In this project, Meta Quest 3 was used, a standalone XR headset, for the visualization of digital twin data managed through the Asset Administration Shell (AAS) (see. the Fig. 6.).

Figure 6. Device for digital twin data visualization

The integration of data is established via Meta Quest Link or Air Link, two wireless streaming technologies developed by Meta. These allow the Meta Quest 3 headset to connect to a host computer over a high-speed Wi-Fi network, enabling the execution of graphically intensive Unreal Engine 5 applications on the PC while streaming the rendered content wirelessly to the XR device. This architecture reduces computational load on the headset and ensures high-quality rendering fidelity, which is essential for displaying dynamic digital twin environments.
The Unreal Engine 5 Engine is used for visualization of Digital Twin and BluePrint language for data collection and control of real model. The example of data transfer by REST API programmed in BluePrint script is shown in Fig. 7.

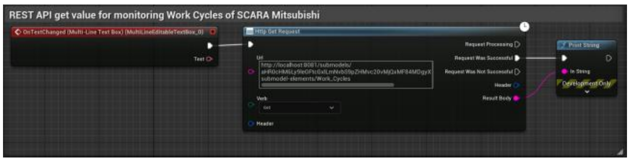

Figure 7. Example of program for monitoring parameters

The editor Unreal Engine 5 is used for visualisation of Digital Twin and BluePrint language for data collection and control of real model. The Unreal Engine application does not operate in isolation; it continuously retrieves real-time operational data from the AAS server. The AAS server holds synchronized data from physical industrial devices (e.g., SCARA or ABB robots, environmental sensors) that are connected via OPC UA. The BluePrint visual scripting system in Unreal Engine 5 is used to implement periodic REST API requests to fetch the latest values from the AAS submodels, that is shown in the Fig.7. The received data includes operational metrics such as robot status, temperature, working cycles, axis coordinates, and environmental conditions. These parameters are parsed and mapped to visual widgets within the XR interface, such as digital readouts, status indicators, and control overlays. For instance, robot joint positions are animated in real-time, and device conditions are visually highlighted using color-coded cues (e.g., green for active, red for error).

Figure 8. Example of DT data visualization in Unreal Engine widget

6 LIMITATIONS OF AAS STANDARD FOR DITIGAL TWIN TRANSFORMATION

During the development of a digital twin using the Asset Administration Shell (AAS) standard based on OPC UA and REST API, with integrated 3D visualization in an XR environment, successful outcomes were achieved. However, several integration challenges and limitations of the standard were encountered. These issues notably affect the scalability of the solution. Furthermore, difficulties arose when connecting real-world systems to their corresponding digital twins. During integration with the XR environment, some performance issues related to hardware and its direct connection to the project were also observed.

Regarding scalability, it became evident that as the number of devices supporting digital twins increases within a production environment, the system must handle significantly more data, AAS shells, and communication endpoints. In centralized deployments, the AAS server may experience performance bottlenecks when processing data from multiple OPC UA sources and responding to high-frequency REST API requests from visualization engines.

While developing AAS shells for specific robots, it was found that no standardized method currently exists for the automatic creation of submodels or their dynamic adaptation based on a device's capabilities or data schemas. As a result, each new device requires manual configuration and testing, which hinders scalability and slows deployment in dynamic manufacturing environments.

During the connection of real devices to the AAS server via OPC UA, the following issues were encountered:

• Network problems, such as incorrect IP address or OPC UA server port, firewalls or proxies blocking connections, high latency, or packet loss.

• Errors in event handling or interactions between the AAS server and OPC UA clients.

• Limited OPC UA functionality on some devices.

• Insufficient device resources (CPU, RAM) to process requests from AAS or OPC UA clients.

In terms of visualization and synchronization with the XR environment, one of the key challenges when using XR headsets—such as the Meta Quest 3—with digital twins is the real-time transmission of data from physical devices into the virtual space without noticeable latency. Although wireless technologies such as Air Link are convenient, they are highly dependent on network stability. If the connection is unstable, issues such as display lag or freezing may occur. This is especially critical in scenarios requiring rapid response, such as robotic control or equipment condition monitoring.

7 CONCLUSION

The article discusses the concept of creating a digital twin based on the Asset Administration Shell (AAS) standard with 3D visualization integration. AAS acts as a digital passport of a physical object, providing structured data representation, access to services and interaction with other components of the digital infrastructure. This work describes the methodology for implementing AAS in industrial processes, in particular, data synchronization between physical devices and the AAS server via OPC UA and transferring this data for visualization using the Meta Quest 3 XR device via REST API.

The study used BaSyx framework, which provides management of AAS, their submodels and communication with external systems. SmartTechLab sensors, ABB IRB 14000 and SCARA Mitsubishi robots were used to implement the digital twin. The results demonstrate the possibility of interactive 3D visualization in Unreal Engine 5, which allows observing the state of real devices in a virtual environment in real time.

Also, the article focuses on the advantages of AAS compared to other standards (ISO 23247, ISO 21838), emphasizing its adaptability to industrial needs, flexibility in data exchange formats (JSON, XML, OPC UA) and compliance with the requirements of Industry 4.0. The work is aimed at expanding the potential of digital twins in visual analysis, simulations and optimization of production processes.

ACKNOWLEDGMENTS

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-23-0591, and by the projects VEGA 1/0700/24, KEGA 014TUKE-4/2023 granted by the Ministry of Education, Science, Research, and Sport of the Slovak Republic.

REFERENCES

[Abdel-Aty 2022] Abdel-Aty, T. A., Negri, E., & Galparoli, S. Asset Administration Shell in Manufacturing: Applications and Relationship with Digital Twin, IFAC-PapersOnLine, 2022, Vol.55, No.10, pp 2533–2538. https://doi.org/10.1016/j.ifacol.2022.10.090

[Bakopoulos 2024] Bakopoulos, E., et al. A Digital Twin and Data Spaces framework towards Resilient Manufacturing Value Chains, IFAC-PapersOnLine, 2024, Vol.58, No.19, pp 163–168. https://doi.org/10.1016/j.ifacol.2024.09.129

[Cainelli 2021] Cainelli, G., & Rauchhaupt, L. Introducing resilience in industrial 5G systems using a digital twin approach. IEEE International Workshop on Factory Communication Systems - Proceedings, WFCS, 2021, pp 33–36. https://doi.org/10.1109/WFCS46889.2021.9483618

[Cutrona 2023] Cutrona, V., et al. Extending factory digital Twins through human characterisation in Asset Administration Shell. International Journal of Computer Integrated Manufacturing, 2023, Vol.37, No.10-11, pp 1214-1231. https://doi.org/10.1080/0951192X.2023.2278108

[Dhouib 2021a] Dhouib, S., & Malenfant, J. AAS Capability-Based Operation and Engineering of Flexible Production Lines. IEEE International Conference on Emerging Technologies and Factory Automation, ETFA, 2021, pp 1-4. https://doi.org/10.1109/ETFA45728.2021.9613435

[Dhouib 2023] Dhouib, S., et al. Interoperability of Digital Twins: Ontology-based Capability Checking in AAS Modeling Framework, IEEE 6th International Conference on Industrial Cyber-Physical Systems (ICPS), 2023, pp 1–8. https://doi.org/10.1109/ICPS58381.2023.10128003

[Drobnjakovic 2023] Drobnjakovic, M., et al. Towards Ontologizing a Digital Twin Framework for Manufacturing, IFIP International Conference on Advances in Production Management Systems, Cham: Springer Nature Switzerland, 2023, pp. 317–329. https://doi.org/10.1007/978-3-031-43666-6_22

[Evans 2022] Evans, B., et al. AAS Implementations - Current Problems and Solutions. Proceedings of the 2022 20th International Conference on Mechatronics - Mechatronika, ME 2022, pp 1-6. https://doi.org/10.1109/ME54704.2022.9982933

[Ferko 2024] Ferko, E., et al. Towards Interoperable Digital Twins: Integrating SysML into AAS with Higher-Order Transformations. Proceedings - IEEE 21st International Conference on Software Architecture Companion, ICSA-C, 2024, pp 342–349. https://doi.org/10.1109/ICSA-C63560.2024.00063

[Gartner 2022] Gartner, S., et al. Blueprint of Digital Twins In High Volume Production Environments Using The Asset Administration Shell. IEEE International Conference on Emerging Technologies and Factory Automation, ETFA, 2022, pp 1-7. https://doi.org/10.1109/ETFA52439.2022.9921624

[Huang 2021b] Huang, Y., Dhouib, S., & Malenfant, J. An AAS Modeling Tool for Capability-Based Engineering of

Flexible Production Lines. IECON Proceedings (Industrial Electronics Conference), 2021, pp. 1-6. https://doi.org/10.1109/IECON48115.2021.9589329

[Juhlin 2022] Juhlin, P., et al. Cloud-enabled Drive-Motor-Load Simulation Platform using Asset Administration Shell and Functional Mockup Units. IEEE International Conference on Emerging Technologies and Factory Automation, ETFA, 2022, pp 1-8. https://doi.org/10.1109/ETFA52439.2022.9921678

[Khan 2022] Khan, L. U., et al. Digital-Twin-Enabled 6G: Vision, Architectural Trends, and Future Directions. IEEE Communications Magazine, 2022, Vol.60, No.1, pp 74–80. https://doi.org/10.1109/MCOM.001.21143

[Kim 2023] Kim, Y.-D., et al. Low-cost construction of digital twins using administration asset shell in augmented reality guide service for machine tool operators. IET Conference Proceedings, 2023, Vol.16, pp 12–18. https://doi.org/10.1049/icp.2023.1729

[Kosse 2022] Kosse, S., et al. Digital Twin Framework for Enabling Serial Construction. Frontiers in Built Environment, 2022, Vol.8, 864722. https://doi.org/10.3389/fbuil.2022.864722

[Liu 2025] Liu, J., et al. Concept, Creation, Services and Future Directions of Digital Twins in the Construction Industry: A Systematic Literature Review. Archives of Computational Methods in Engineering, 2024, Vol.32, No.1, pp 319-342. https://doi.org/10.1007/s11831-024-10140-4

[Melo 2024] Melo, V., et al. Design of an ISO 23247 Compliant Digital Twin for an Automotive Assembly Line. IEEE 7th International Conference on Industrial Cyber-Physical Systems (ICPS), 2024, pp 1–6. https://doi.org/10.1109/ICPS59941.2024.10640052

[Minh 2024] Minh, T. B., et al. A Digital Twin Implementation Framework for a Collaborative Robot Based on Iso 23247, The International Conference on Sustainable Energy Technologies, Singapore: Springer Nature Singapore, 2024, pp. 747–755. https://doi.org/10.1007/978-981-97-1868-9_74

[Negri 2023] Negri, E., & Abdel-Aty, T. A. Clarifying concepts of Metaverse, Digital Twin, Digital Thread and AAS for CPS-based production systems. IFAC-PapersOnLine, 2023, Vol.56, No.2, pp 6351–6357. https://doi.org/10.1016/j.ifacol.2023.10.818

[Nguyen 2024] Nguyen, Q.-D., et al. Manufacturing 4.0: Checking the Feasibility of a Work Cell Using Asset Administration Shell and Physics-Based Three-Dimensional Digital Twins. Machines, 2024, Vo.12, No.2, 95. https://doi.org/10.3390/machines12020095

[Park 2021] Park, K. T., Yang, J., & Noh, S. Do. VREDI: virtual representation for a digital twin application in a work-center-level asset administration shell. Journal of Intelligent Manufacturing, 2021, Vol.32, No.2, pp 501–544. https://doi.org/10.1007/s10845-020-01586-x

[Rongen 2023] Rongen, S., Nikolova, N., & van der Pas, M. Modelling with AAS and RDF in Industry 4.0. Computers in Industry, 2023, 148. https://doi.org/10.1016/j.compind.2023.103910

[Salama 2024] Salama, F., et al. HoloWoT: A First Step Towards Mixed Reality Digital Twins for the Industrial Internet of Things. Proceedings of the ACM/IEEE 27th International Conference on Model Driven Engineering Languages and Systems, 2024, pp 318–321. https://doi.org/10.1145/3652620.3688243

[Schmitt 2019] Schmitt, J., et al. Authorization in asset administration shells using OPC UA. At - Automatisierungstechnik, 2019, Vol.67, No.5, pp 429–442. https://doi.org/10.1515/auto-2019-0020

[Stark 2019] Stark, R., Fresemann, C., & Lindow, K. Development and operation of Digital Twins for technical systems and services. CIRP Annals, 2019, Vol.68, No.1, pp 129–132. https://doi.org/10.1016/j.cirp.2019.04.024

[Tao 2018] Tao, F., et al. Digital twin-driven product design, manufacturing and service with big data. The International Journal of Advanced Manufacturing Technology, 2018, Vol.94, No.9–12, pp 3563–3576. https://doi.org/10.1007/s00170-017-0233-1

[Ye 2023] Ye, X., et al. Implementing Digital Twin and Asset Administration Shell Models for a Simulated Sorting Production System. IFAC-PapersOnLine, 2023, Vol.56, No.2, pp 11880–11887. https://doi.org/10.1016/j.ifacol.2023.10.600

[Yoon 2023] Yoon, S. Building digital twinning: Data, information, and models. Journal of Building Engineering, 2023, Vol.76, 107021. https://doi.org/10.1016/j.jobe.2023.107021

[Zezulka 2022] Zezulka, F., et al. The Ideas of Industry 4.0: Seven Years after. IFAC-PapersOnLine, 2022, Vol.55, No.4, pp 145–150. https://doi.org/10.1016/j.ifacol.2022.06.024

CONTACTS:

Ing. Anastasiia Nazim
Assoc. Prof. Kamil Zidek
Asst. Prof. Michal Duhancik
Technical University of Kosice,
Faculty of Manufacturing Technologies with the seat in Presov
Bayerova 1, 080 01 Presov, Slovakia
anastasiia.nazim@tuke.sk; kamil.zidek@tuke.sk; michal.duhancik@tuke.sk