# Towards an Asset Administration Shell scenario: a use case for interoperability and standardization in Industry 4.0


Miguel A. Iñigo
*Innovation and Technology dept.*
*MONDRAGON S.Coop.*
Arrasate / Mondragón, Spain
minigo@mondragoncorporation.com

Alain Porto
*ICT and automation dept.*
*IDEKO S.Coop.*
Elgoibar, Spain
aporto@ideko.es

Blanca Kremer
*ICT dept.*
*Ikerlan Technology Research Centre, BRTA.*
Arrasate / Mondragón, Spain
bkremer@ikerlan.es

Alain Perez
*Electronics and Computer Science dept.*
*Mondragon University*
Arrasate / Mondragón, Spain
aperez@mondragon.edu

Felix Larrinaga
*Electronics and Computer Science dept.*
*Mondragon University*
Arrasate / Mondragón, Spain
flarrinaga@mondragon.edu

Javier Cuenca
*Electronics and Computer Science dept.*
*Mondragon University*
Arrasate / Mondragón, Spain
jcuenca@mondragon.edu



***Abstract*—The new paradigm of the Industry 4.0 centers on the digitalization of assets to realize a new industrial revolution. Standardization and interoperability are key for the successful implementation of this digitalization strategy. Among the different standardization and interoperability initiatives, Asset Administration Shell (AAS) proposes a standardized electronic representation of industrial assets enabling Digital Twins and interoperability between automated industrial systems and Cyber Physical System (CPS). In this context, Mondragon Corporation has launched several initiatives to boost the digitalization of its industries. Although implementation of the AAS in real industrial scenarios is not widespread, Mondragon Corporation has identified this initiative as a key enabler for manufacturing companies within its group. This paper presents a case study on the application of the AAS in an industrial context. The AAS initiative is implemented through integrating a Machine Tooling ecosystem with a robotic arm. This implementation facilitates the discovery and integration of grinding machines with other components or machines in a production plant, validating the AAS in a manufacturing scenario.**



***Index Terms*—Asset Administration Shell, Industry 4.0, Interoperability, Manufacturing, Standardization**


## I. Introduction

The development of Information and Communication Technologies (ICT), and its implementation in industrial contexts allow the coexistence and integration of Operation Technologies (OT) of the manufacturing world with the Information Technologies (IT) used on the Internet. In the near future technologies such as Data Analysis, Machine Learning, Big Data, IoT architectures, Cybersecurity or Additive Manufacturing will have an impact on industrial technologies as far as manufacturing, maintenance or collaboration among machines is concerned. New products based on services working in collaboration with Cyber-Physical Systems (CPS), sensors, devices, other machines or virtual representations of the physical world (Digital Twin) will be demanded. This new ecosystem will realise a new industry paradigm, i.e. the intelligent factory vision for the Industry 4.0. To achieve that goal, all those models, conceptualizations and enabling technologies of the Industry 4.0 have to provide horizontal, vertical and end-to-end integration and interoperability. This is not an easy task due to the low level of automation technology flexibility, high specificity of industrial assets and the lack of interoperability between heterogeneous systems (industrial silos). In addition, the representation of industrial assets is not clearly standardized to support identification and characterization for the factories of the future. Industrial products, services and processes need to comply with standards and enable interoperability among heterogeneous systems to fulfil the requirements of the Industry 4.0 and enable integration with their virtual representation as a digital twin throughout their life cycle.

To support this vision, Standard Development Organizations (SDOs), industrial organizations, joint committees and working groups are fostering the definition of standards for smart manufacturing. Moreover, these organizations work on the development of Smart Manufacturing Reference Models (such as RAMI 4.0, IIRA or SME). Among various initiatives, there is Asset Administration Shell (AAS), proposed by the German platform Industrie 4.0, which aims to describe an asset electronically in a standardized manner enabling interoperability between different assets in a plant. AAS supports the idea of standardized automated industrial systems, industrial


Part of this work was carried out by the Software and Systems Engineering research group of Mondragon Unibertsitatea (IT1326-19), supported by the Department of Education, Universities and Research of the Basque Government.

978-1-7281-4973-8/20/$31.00

assets and CPS throughout the manufacturing life cycle within a digital environment where the Digital Twin approach is feasible. The AAS initiative plays a relevant role for further developments in the Industry 4.0 landscape. However, even though several reports have been published, due to the complexity of the standardization ecosystem there are still no real scenarios implemented for the industry. The main objective of this paper is to present the implementation of the AAS in an industrial scenario. The use case considers a plant composed by a *robotic arm*, a *grinding machine* and a semantic harmonization layer. The paper is structured as follows: (I) Section II presents the related work; (II) Section III outlines the motivation behind; (III) Section IV introduces the use case; (IV) Conclusions and future work are presented in Section V.

## II. Related Work

### A. Standardisation landscape

The research activity of standardisation organizations in the development of the technological requirements for Industry 4.0 and the Industrial Internet of Things (IIoT) is intense and result in a very heterogeneous landscape. Many standardisation initiatives are being developed simultaneously, either individually (International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), International Telecommunication Union (ITU), Worldwide Web Consortium (W3C) and Internet Engineering Task Force (IETF)) or in partnerships (ISO/IEC joint technical committee 1 (ISO/IEC JTC 1), ISA (International Society of Automation), IEEE (Institute of Electrical and Electronics Engineers), OneM2M (standards initiative for machine-to-machine communications and the Internet of things), IEC/SEG7 (smart manufacturing), the ISO SMCC (smart manufacturing coordinating committee)). Additionally, other industry initiatives and open platforms contribute to the standardisation ecosystem: e.g. Industrial Internet Consortium (IIC), Platform Industrie 4.0, Standardisation Council Industrie 4.0 (SCI 4.0), Labs Network Industrie 4.0 (LNI 4.0) or the Alliance for the Internet of Things Innovation (AIOTI).

In [1], the complex current landscape of Standards Setting Organisations (SSOs) is presented, identified by the AIOTI. It also shows the distribution of SSO activities across different application domains and the underlying communication infrastructure. The two most representative SDOs are *ISO/TC184 automation systems and integration* and *IEC/TC65 industrial-process measurement, control and automation*. Within IEC/TC65, the new *Task Force 8 Digital Twin and AAS* has been created.

In order to categorize and enumerate the most relevant standards for Industrial Internet of Things and present a bounded landscape, we provide a list of reports and standards associated with Smart Manufacturing References Models (SMRM):

- *Current Standards Landscape for Smart Manufacturing Systems* [2] by National Institute of Standards and Technology (NIST) of the United States of America.
- *German Standardization Roadmap Industry 4.0* [3] and *Structure of the Administration Shell, the continuation of the development of the reference model for the Industrie 4.0 component* [4] by German DIN, DKE and VDE.
- *National Intelligent Manufacturing Standards Architecture Construction Guidance* [5] by the Ministry of Industry and Information technology (MIIT) and the Standardization Administration of China (SAC).
- *Standardization for Industry 4.0*[1] by Spanish standardization bodies UNE / AENOR.

For a valuable overview and summary of relevant standards for smart manufacturing management we can refer to [6]. [7] also describes different architectures, reference models and standard frameworks.

### B. Smart Manufacturing Reference Models

Reference architectures and models offer simple and generally proven solutions that support a company in setting up its entire production on the basis of a jointly agreed standard architecture. According to [8], a reference architecture in information technology is a reference model for the representation of concepts of the physical world guided by a methodology containing rules with the purpose of reflecting that physical world in the information world. Reference architectures and models are essential for the integration of IT/OT systems. Engineering tools are also necessary in order to ensure seamless integration of technical systems and related processes.

In order to develop a smart manufacturing solution and push a systematic standardisation, industrial organizations and SDOs have developed different architectures over the last years. Because of the large heterogeneity of the architectures and models, SDOs and technical groups have started liaisons and have undergone cooperation in order to achieve interoperability between the standards and contribute to harmonization. The most representative reference architectures are:

- **RAMI 4.0 (Reference Architecture Model Industrie 4.0)** is an adaptation and expansion from the Smart Grid Architecture Model (SGAM) to meet the requirements of Industry 4.0 [3]. The RAMI 4.0 consists of a three-dimensional model to represent the I4.0. The corresponding axes of the model are described in [9].
- **Smart Manufacturing Ecosystem (SME)** developed by NIST, proposes SME to encompass manufacturing pyramid with three dimensions – product, production, and enterprise (business) [10].
- **The Industrial Internet Reference Architecture (IIRA)** [11] is a standardized open architecture based on industrial production systems.

### C. Asset Administration Shell

An Administration Shell or Asset Administration Shell (AAS) is a ”standardized digital representation of an asset. This concept is the corner stone of the interoperability between

[1]UNE 0061:2019, Industry 4.0. Management system for digitization. Requirements assessment.

the applications managing the manufacturing systems. AAS identifies the Administration Shell and the assets represented by it, holds digital models of various aspects (submodels) and describes technical functionality exposed by the Administration Shell or respective assets" [12] (see figure 1).

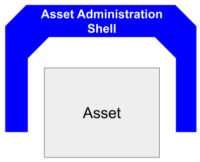


Fig. 1. Graphical representation of an asset and its AAS.

In 2017, [13] proposed a life cycle for a plant in Industry 4.0 and compared it with the life cycle of a plant 3.0. In this context, they discuss the terms "Asset Administration Shell" and "Digital Twin" and classify them in relation to the plant life cycle 4.0. Regarding the terms "Asset Administration Shell" and "Digital Twin", the authors think that both terms convergence against each other. Therefore, the authors conclude that the Digital Twin in a future and fully enriched version can be treated as a synonym for the AAS and that the restriction of the Digital Twin on pure simulation model aspects is not sufficient.

As an approach to develop a digital representation of Industry 4.0 components, [14] bases on semantic knowledge representation formalisms. They propose a Semantic I4.0 component using RDF for data interoperability, HTTP Unique Respurce Identifiers (URIs) for global unique identification of the components, SPARQL for querying the data, translations of existing standards into RDF vocabularies and semantic web technologies to facilitate multilingualism. Moreover, [15] developed "both a landscape of Industry 4.0 related standards and the Standard Ontology (STO) for the semantic description of standards and their relations" [6]. They populated the ontology with standards such as RAMI or NIST and important concepts for the domain such as the Administration Shell submodel.

According to [16], AAS is meant to be implemented in any technology (XML + services, API REST + JSON, OPCUA...). Due to its importance of the RAMI 4.0 reference architecture, AAS has been adopted as the basis for Asset representation in this work. Considering that the desired implementation of AAS has a strong relation with the industrial environment, it is necessary to use a "industrial-friendly" technology such as OPCUA. Our first approach considered for AAS implementation was open Asset Administration Shell (openAAS[2]) by *Chair of Process Control Engineering RWTH Aachen University* and *ZVEI*. Nevertheless, this AAS structure was later updated for implementation in our case using University of Catania's CoreAAS [3]. This model extends the general OPCUA types with types of objects, references and data that are defined in the structures and rules of the AAS metamodel specified in [12]. [17] provides an implementation of the AAS called NOVAAS, based on well established REST technologies. This approach is interesting but RAMI4.0 recommends OPCUA as the bridge between IT and OT. Moreover, a OPCUA mapping for AAS is already available in [12]. Therefore, our industrial case study implements AAS using that communication technology.

[2]https://acplt.github.io/openAAS

[3]https://github.com/OPCUAUniCT/coreAAS

## III. Motivation

Automation is evolving from a hierarchical model towards an integrated network of smart automation devices. In this scenario, it is essential to develop interoperability tools for integrating assets in the Industry 4.0 network [18]. To overcome such integration challenges, AAS can be used for automatic self-conducted machine data exchange and for interaction and integration with the industrial environment. In order to promote standardization and interoperability from an smart factory perspective, Mondragon Corporation[4] participates in several initiatives to boost digitalization among the cooperatives in its industrial group. Mondragon Corporation is the embodiment of the cooperative movement and forms the 1st industrial group in the Basque Country and the 7th in Spain. This collaboration is materialized through digital transformation European projects (Arrowhead[5], Mantis[6], Productive 4.0[7] and QU4LITY[8]). Along its Research Technological Organizations (RTO) partners (Ikerlan, Mondragon University and Ideko), Mondragon proposes different use cases for testing and validating AAS possibilities within its companies. These use cases set the basis for other companies within Mondragon Corporation to adopt these new technologies. The context selected for the use case in this paper involves a plant using a machine tool. The machine tool manufacturer is DANOBATGROUP [9] (cooperative in Mondragon Group), who needs to find new solutions in order to integrate their new machines within the Industry 4.0 tissue.

## IV. Use Case

The use case presented in this paper (see Figure 2) creates two AASs (Robotic Arm AAS and Grinding Machine AAS) and tests the interoperability between them using a semantic integrator. To improve its deployment, Docker[10] has been used.

### A. Robotic Arm's AAS

An AAS has been implemented over a RoboticArm demonstrator. This demonstrator was based on a SainSmart Robotic Arm[11], a Raspberry Pi and a controller board for the Adafruit[12] servos.

[4]https://www.mondragon-corporation.com/en/

[5]https://www.arrowhead.eu/

[6]http://www.mantis-project.eu/

[7]https://productive40.eu/

[8]https://qu4lity-project.eu/

[9]https://www.danobatgroup.com/es/danobat

[10]https://www.docker.com/

[11]https://www.sainsmart.com/products/4-axis-desktop-robotic-arm-assembled

[12]https://www.adafruit.com/product/2327

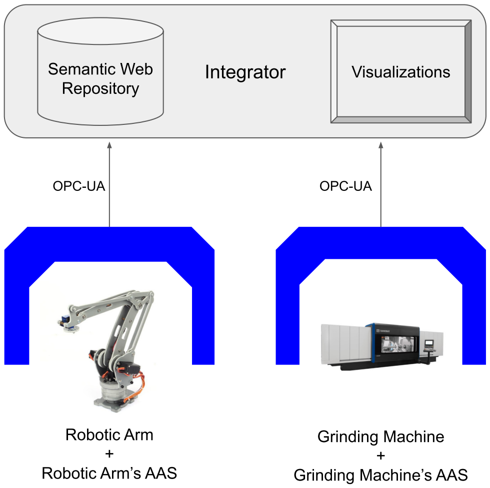


Fig. 2. Architecture of the use case.

The robotic arm (see Figure 3) has 4 axes controlled by four servos. The function of the Raspberry Pi is to control the movement, through a standard keyboard connected by USB, and to serve the information model of the RoboticArm. The keystrokes will be transformed into the appropriate signals for the servos through the Adafuit Servo Hat card. This small board is connected above the Raspberry Pi and adds the necessary interfaces to control the servos via pulse-width modulation (PWM) signals.

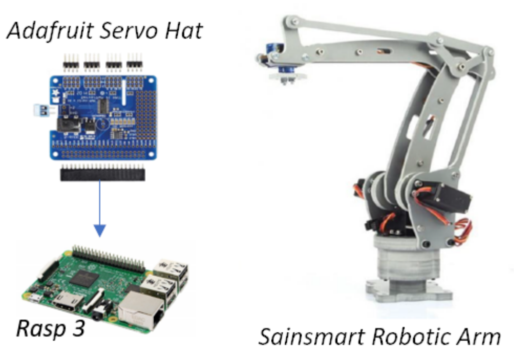


Fig. 3. Components of the Robotic Arm.

Initially this part of the demonstrator (developed by IKERLAN) contained an OPCUA server that published the OPCUA Model Companion-Specification for Robotics as defined in *OPC 40010-1 - Robotics Part 1*[13]. This specification provides information about asset configuration and condition monitoring. It also presents the model for a motion device type and its axis type component.

[13]*OPC 40010-1 - Robotics Part 1: Vertical Integration. OPCUA Information Model release.* viewed 13 Jan 2020, https://opcfoundation.org/developer-tools/specifications-opc-ua-information-models/opc-unified-architecture-for-robotics/

This model facilitates interoperability in scenarios where communication with different types of robots is necessary, making it easier for applications to monitor or act on them. AAS goes further and proposes a more generic model in which aspects of life cycle as well as semantic content will be incorporated.

The demonstrator has been transformed to consider the RoboticArm as an Asset and the OPCUA server in the Raspberry Pi has been modified to publish the Administration Shell of the RoboticArm asset instance, making use of an open source OPCUA implementation (open62541).

Identification, Documentation and Condition Monitoring have been defined as sub-models for the Asset RoboticArm. The sub-model Identification contains all properties related to the identification of the asset used in the demonstrator (manufacturer, model, serial number). The Documentation sub-model contains information about the files that document the asset (datasheet, maintenance manual). The submodel Condition Monitoring contains some of the properties defined in the AxisType and that are relevant for our demonstrator such as the motion profile and the actual position of each axis of the RoboticArm. Although the metamodel defines the concept of Operation, CoreAAS does not have it defined among its types, however its implementation of the AAS PropertyType allows not only reading but also writing the attribute Value. Thus, to act on the RoboticArm, instead of Operations new Properties have been added to the sub-model in order to move the axes. Axis_X_SetPosition, Axis_Y_SetPosition and Axis_Z_SetPosition Value will be set and the RoboticArm will move according to that value. Each element of these sub-models will have a semanticId defined, using custom URIs, with the aim that the final orchestrator can interact with the different properties of the submodel. Figure 4 shows a generic OPCUA client connected to the RoboticArm AAS.

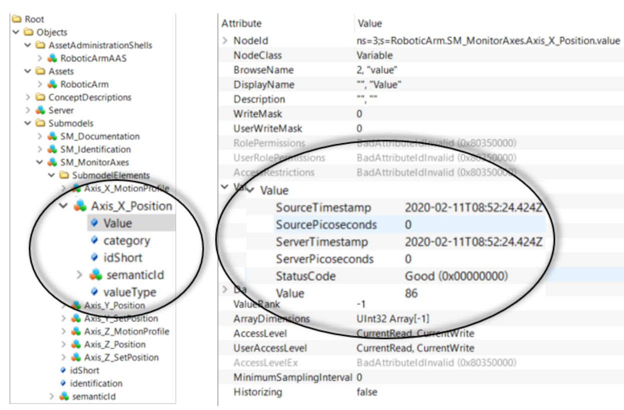


Fig. 4. Snapshot of an OPCUA client connected to the Robotic Arm AAS.

## *B. Grinding Machine's AAS*

The AAS has been implemented over DANOBAT's HG-72 grinding machine. The idea behind is to make the AAS implementation easily exportable to other grinding machines or even different kind of machine tools.

The developed architecture is shown on Figure 5. The communication with the machine is done using DANOBAT's data system solution and its IOT gateway, called 'SAVVY BOX'. This smart box acts also as a IT/OT gateway that transforms the custom field-bus protocols from different manufacturers (such us Siemens S7, Modbus, OPCDA, EherCAT...) onto well known IT data exchange protocols such as API REST or OPCUA.

Recently, a new feature has been added that allows the box to exchange information using UMATI (Universal Machine Tool Interface), a interface that standardizes the way the machine tools share information over OPCUA [14].

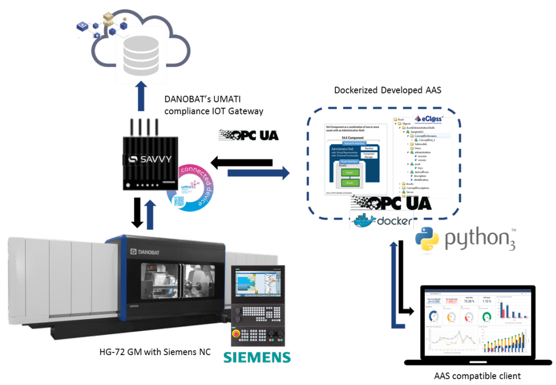


Fig. 5. Grinding Machine's AAS

Using the UMATI interface, the data can be easily extracted from the machine and in a standard manner for all UMATI compliant machines. To build the AAS, an abstraction layer has been placed above UMATI, using python programming language. This software gathers the data coming from the UMATI interface and adds all semantic information to build the AAS according to the document [12] and exposes it as an OPCUA server. The semantic information has been added using custom URIs for uniquely identifying each one of the elements. Part of the model information of the AAS implemented in OPCUA can be seen in figure 6. Specifically, the exposed data from the machines can be seen in the next bullet points:

- CustomName: Machine's name according to catalogue.
- JobStatus: An integer that indicates the status according to UMATI standard.
- Manufacturer: The name of the manufacturer ( in this case Danobat).
- Absolute Positions: X, Y and Z absolute positions of the machine.

### C. Integrator

The integrator works as the plant organizer. It manages the manufacturing workflow and the communication with the different assets. It consists of 2 parts:

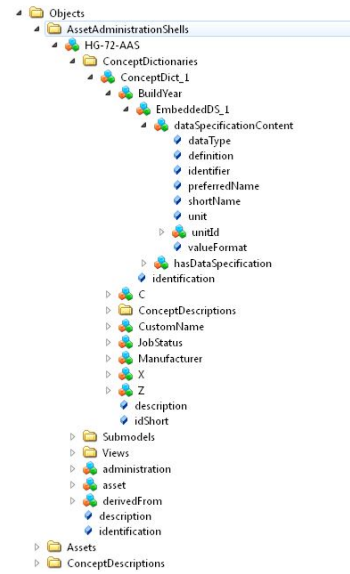


Fig. 6. Grinding Machine's AAS Model Information

- The main part (OPCUA client and visualization) is developed using Node-RED[15].
- Semantic database (GraphDB[16]) were data are stored in triplets.

A semantic representation for each AAS is passed to the integrator so it can use the assets (Figure 7). That way, if an asset changes or updates, a new representation is passed. Then, the integrator communicates with the assets using OPCUA and visualizes their data (Figure 8). That way, plant managers know the current state of the plant and can interact with the different assets.

The integrator updates the semantic database on intervals. Moreover, GraphDB offers a SPARQL endpoint so external applications can also query it. Therefore, the different Assets and their properties are also available for external applications.

## V. Conclusions and Future Work

In this case study, the current state of the AAS has been validated. Moreover, the feasibility of this technology has been proved in order not only to represent heterogeneous industrial assets and their digital twin, but also to enable the interoperability between those assets in a manufacturing plant. The use case also uses standards proposed by the RAMI4.0 reference architecture.

Regarding to AAS and its maturity, we conclude that it is a promising standardization initiative and opens the door to further development in the industrial context. Although Platform Industrie 4.0 has put much effort on this direction, there is a lack of sub-model standardization. Regarding to AAS and its adoption in the industrial context, we believe that it is important to explore the integration of AAS on interoperability

[14]https://vdw.de/en/technology-and-standardisation/umati-universal-machine-tool-interface/

[15]https://nodered.org/

[16]http://graphdb.ontotext.com/

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@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rami: <https://w3id.org/i40/rami#> .
@prefix om: <http://www.wurvoc.org/vocabularies/om-1.8/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix il: <http://ikerlan.es/aas#> .

il:AxisXPositionValue a owl:ObjectProperty ;
  rdfs:domain il:SMAxisPosition ;
  rdfs:range om:Measure ;
  rdfs:label "Robotic Arm's X Axis Position"@en ;

il:SMAxisPosition rdf:type owl:Class ;
  rdfs:subClassOf rami:Submodel .

il:RoboticArmAAS rdf:type owl:Class ;
  rdfs:subClassOf rami:AssetAdminShell .

il:RoboticArmAAS1 a il:RoboticArmAAS ;
  rami:hasSubmodel il:SMAxisPosition1 ;
  rami:hasAdminShellId "RA_AAS1"^^xsd:string ;
  rdfs:label "Robotic Arm AAS 1"@en .

il:SMAxisPosition1 a il:SMAxisPosition ;
  il:AxisXPositionValue il:MeasureAxisXPosition1 ;
  il:AxisXSetPositionValue il:AxisXSetPosition1 ;
  il:AxisYPositionValue il:MeasureAxisYPosition1 ;
  il:AxisZPositionValue il:MeasureAxisZPosition1 ;
  rami:subModelID "SM_AP1"^^xsd:string ;
  rdfs:label "Axis position Submodel 1"@en .

il:MeasureAxisXPosition1 a om:Measure ;
  om:hasUnit om:degree ;
  rdfs:label "X Axis Position in degrees 1"@en ;
  om:hasNumericalValue "161.0"^^xsd:float .
```

Fig. 7. Asset semantic representation example using turtle.

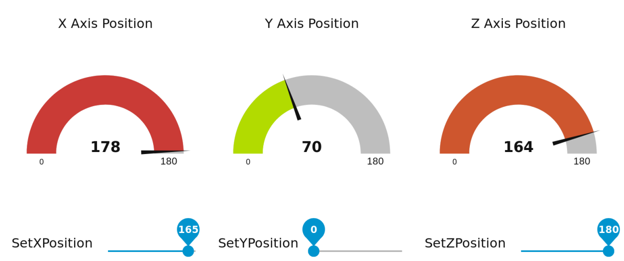


Fig. 8. Robotic Arm axes position visualizations and control using Node-RED Dashboard.

platforms, such as Arrowhead. The adoption of AAS in these platforms could be a key factor for success.

In relation to our experiment, we plan to extend the implementation of the AAS to validate it in a larger scenario. That way, a common methodology could be developed to integrate AAS in any manufacturing plant.

Regarding security, AAS itself is a representation of the asset, but does not implement security measures. The implementations of the communication technologies should be the ones managing this aspect.

Finally, our system was designed to adapt to machine updates in the plant. Similar machines offering the same functions and parameters can be switched in the plant providing their semantic representation. Even if both developed AASs contain and offer a URI for each parameter/function, the current OPCUA client does not support the reading of those URIs. Therefore, the integrator does not support that functionality yet. A future update or a change on the used client is necessary.

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