AI-based IIoT Digital Twin: A practical AAS approach for production monitoring

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INTERX and Fraunhofer IWU have collaborated together to generate a practical use case of AI-based IIoT Digital Twin. Both institutions have employed AAS as a standard to collect the IoT data, generate AI models, and visualize on Digital Twin. Fraunhofer IWU offered smartNOTCH IIoT - a novel sensor solution for transparency in forming processes, and INTERX used their platform consisted of quality prediction AI solution (Quality.AI), recipe optimization AI solution (Recipe.AI) and digital twin solution (INTERX.DT) to develop the use case. The main underlying thread connecting different systems was AAS.

Let's go through what the consortium has developed and shown at the Hannover fair 2023. A brief video summary of the use case could be found at the following Youtube link: bit.ly/3XPqs1U

Importance of process monitoring in forming technology

Agility and efficiency in production are the prerequisites for successfully producing companies in metal forming technology. Detailed process and equipment knowledge in all operating states is a decisive factor here and has numerous positive effects. Not only is there less scrap, but machine downtimes are also reduced and root cause analysis is faster.

Figure 1 Joint Korea-Germany R&D seminar at Hannover fair 2023 (From left: Wonju Park (Chairman of Korea Industry 4.0 Association), Jason Park (CEO of INTERX), Kwanghyun An (President of Korea Smart Manufacturing Office), Meik Billmann (General Manager of IDTA), Robin Kurth (Group Leader of Fraunhofer IWU) and Hail Jung (CTO of INTERX).

In addition to the approach of equipping machines at system level with individual sensors, retrofit solutions at component level are playing an increasingly important role, for example in retrofits. In the chain from the machine component to the technology, the tool interface of forming machines can be regarded as an ideal source of information - close to the process and integral to the machine.

smartNOTCH - robust and flexible

At Fraunhofer IWU, a holistic approach is taken to monitoring the forming machine and process. The focus is on the comprehensive determination of information using the least possible number of robust sensors that can be easily retrofitted. Decentralized sensors such as the smartNOTCH record process variables and use them for process and quality monitoring during the forming process by means of an intelligent evaluation algorithm. Without affecting the forming process or the machine properties, the tool clamping surface of presses can become valuable data sources for cognitive production. With the information, it is possible to make the tooling process and product startups more knowledge-based and thus more efficient, as well as to reliably monitor series processes.

The measurement concept of smartNOTCH is simple. The small sensors can be installed directly in the T-slots, regardless of size, within a very short time.

This makes it possible to collect information at several points in the press table or ram, even directly under the forming tool - inline and robust. Information accumulating at multiple points can be analyzed individually or correlated and linked to other data sources. Trend analyses are possible during the production process, and process irregularities that lead to changes in process forces or their distribution can be reliably detected. A fast reaction in case of need is thus possible - if desired directly from stroke to stroke.

From sensor data to digital twin

If even more information is to be extracted from the measurement signals, an analysis procedure developed at Fraunhofer IWU is used. The basis is then formed by system information that describes the reaction behavior of the forming machine. With this knowledge, algorithms are built up with which the measurement data from smartNOTCH can be analyzed on a model basis - a digital twin is created. This concept makes it possible, for example, to capture elastic holistic information on deformation situations or force distributions with smartNOTCH, although real sensors are only used at a few points. We call this concept Digital Twin - based Virtual Sensors.

Gathering the sensor data using AAS

What is important in gathering sensor data and generating AI models from them is to have a standard. Otherwise, we would have to create a customized data collection method for each type of sensor. Thus, considering the scalability and versatility, we have employed Asset Administration Shell (AAS) to make a standard of sensor data collection. smartNOTCH was our first example.

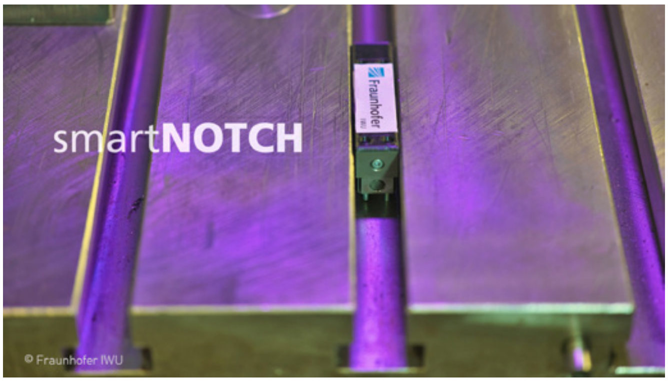

Figure 2 A prototype image of SmartNOTCH sensor developed by Fraunhofer IWU.

We have used AAS because of interoperability, data transparency and ease of integration of IT and OT. AAS enables seamless interoperability between different industrial systems, machines, and components. It establishes a common language and format for exchanging information about assets, regardless of their underlying technology or manufacturer. Furthermore, AAS improves transparency by providing comprehensive and up-to-date information about assets throughout their lifecycle. This includes not only static information like specifications and configurations but also dynamic data such as sensor readings, maintenance logs, and usage patterns. Lastly, we believe AAS bridges the gap between Information Technology (IT) and Operational Technology (OT) domains. It enables the integration of digital systems with physical assets, allowing real-time monitoring, control, and optimization of industrial processes. For these reasons, we have employed AAS as a standard to collect the sensor data and generate AI models from it.

To employ AAS, we have first identified an asset, which is assigning a unique identifier to each asset to ensure its unambiguous identification within the AAS framework. We then developed the asset structure. We defined the structure of the AAS based on the asset's hierarchical or functional composition. This includes specifying the relationships between the asset (e.g., smartNOTCH) and its subcomponents or related assets (e.g., forming machine).

Then, the important next step is to determine the relevant properties and characteristics of the asset that need to be represented in the AAS. This can include physical parameters (e.g., time-series data from smartNOTCH), performance metrics, maintenance schedules, and other relevant information. Based on the structure, we then established the data models necessary to represent the sensor data collected from the asset. This involves defining the structure, semantics, and units of measurement for the different types of data.

Generating AI models on AAS acquired data

Based on the well-structured data gathered from AAS, INTERX have used their Quality.AI and Recipe.AI solutions to generate quality prediction AI model and production condition optimization AI model. The idea is that when the product is defective, then the time-series values generated by the smartNOTCH draw a different pattern compared to that of non-defective production. By using the Quality.AI solution of INTERX, we then created AI models to determine whether the production data collected from smartNOTCH is defective or not.

If the product is determined to be defective, then it is important to understand the reason for the defection and how to change the setting values to avoid further defection. INTERX offers a Recipe.AI solution to guide the operators how to alter their

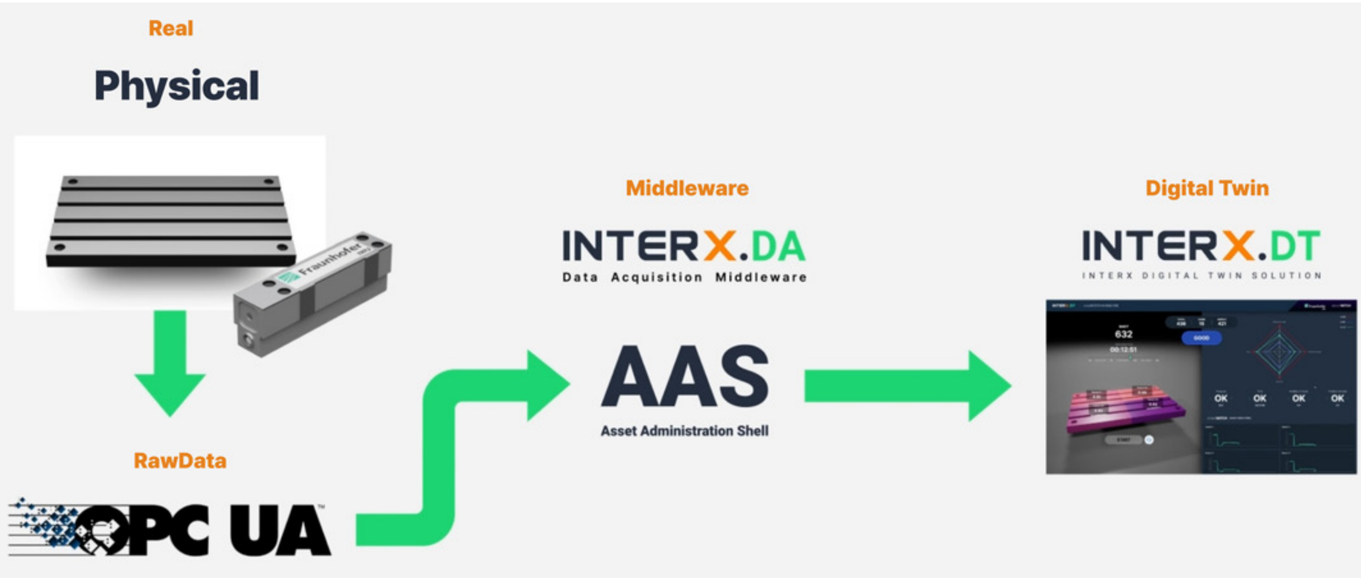

Figure 3 A flowchart of how IIoT and machine data are gathered through AAS and how other AI or Digital Twin solutions are using AAS-gathered data.

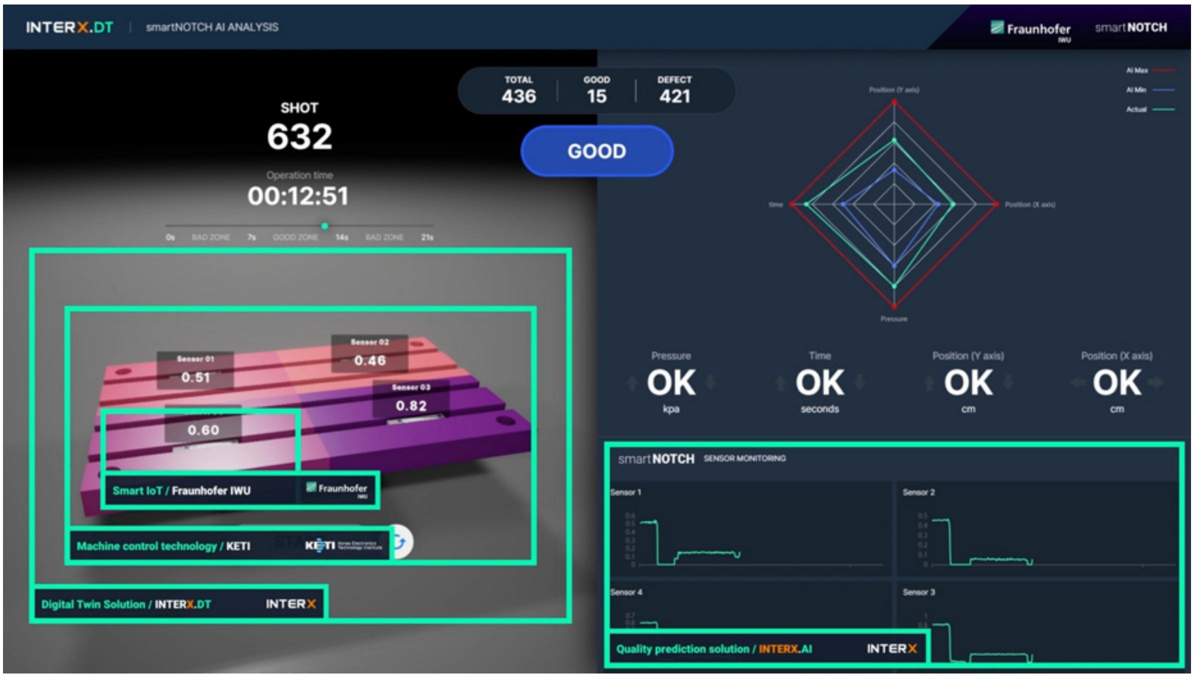

Figure 4 A Digital Twin visualizing the press table, SmartNOTCH, quality prediction AI model and recipe optimization AI model.

production setting values when defect occurs. Based on the optimization AI models, Recipe.AI provides the reason for the defect and how to change setting values.

Digital Twin as a final layer to visualize all work

Lastly, it is important to visualize sensors, AAS systems, machine data and AI solutions in a single layer so that users can easily make decisions. INTERX offers a Digital Twin solution, INTERX.DT, to combine all different works in a single layer. INTERX.DT has a feature to create a Digital Twin representation of the physical sensor in a virtual environment. It associates the relevant metadata and properties of the sensor with its Digital Twin counterpart. The solution then visualizes the digital twin of the sensor, including its physical appearance, location, and any other contextual information. We then provide real-time or near-real-time updates to the digital twin based on the sensor's data readings.

If the sensor is attached to a different machine or a system, we then can develop a Digital Twin of the machine or equipment to which the sensor is attached. Similarly, INTERX.DT establishes the relationship between the sensor's digital twin and the machine's Digital Twin, reflecting their physical connection. We then display the sensor's position on the machine within the digital twin representation and enable the visualization of sensor data and associated attributes within the context of the machine's Digital Twin. What is then important is to incorporate AI models into the Digital Twin environment. We use API of AI models to integrate the AI model's outputs, such as predictions, anomalies, or recommendations, with the Digital Twin representation. We then visualize the AI model's results alongside the sensor data, providing insights and actionable information within the Digital Twin environment. Using independent Digital Twin components such as sensor, machine and AI models, INTERX.DT then utilizes appropriate visualization tools or interfaces to present the sensor, machine, and AI model information within the digital twin environment. Our solution displays the sensor data in a visually meaningful way, such as graphs, charts, or gauges, highlighting relevant trends, patterns, or anomalies. Our solution enables interactive features, allowing users to explore and manipulate the digital twin visualization to gain insights and perform analyses. One important feature of Digital Twin is to provide and update information real-time. Our INTERX.DT establishes mechanisms for real-time data synchronization between the physical sensor, the Digital Twin, and the associated AI models. We ensure that changes in the sensor data, machine status, or AI model outputs are reflected promptly in the digital twin environment. We also provide notifications or alerts within the digital twin visualization to inform users of critical events or deviations detected by the sensor or AI models.

By leveraging Digital Twin technology in this manner, we can create a comprehensive and immersive visualization tool that integrates sensors, their physical context, and AI models. This enables users to gain a deeper understanding of the sensor data, monitor the machine's behavior, and leverage AI-powered insights for decision-making and optimization.

Future work on Digital Twin

In the next project phase, the consortium will further develop the solution and bring it into application on real production systems. The focus of the development will be on a fast integration of the sensor and software solution as well as an extended analysis and interpretation of the sensor and model data.

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