Anomaly detection at automotive press shop: Efficient and resource-saving production

Highlights:

- The pressing process in auto production (pressing metal plates into special molds to produce different vehicle parts) is an important but energy-intensive step
- The process can have a significant impact on the entire production flow and the manufacturing cost of a vehicle
- An international auto manufacturer used the Phoenix Contact Digital Factory now strategy to detect errors at an early stage
- This approach minimizes downtime and ensures consistent product quality

By using anomaly detection, the manufacturer can now identify potential problems with the motors at an early stage and act proactively to minimize downtime and ensure product quality.

Customer profile:

The customer is a large automotive manufacturer.

Challenge:

A more efficient pressing process

Automotive companies are under considerable global competitive pressure, so they are always looking for ways to produce more efficiently. At the same time, the automotive industry is seen as a driver of innovation and a role model for other sectors. For this reason, they are confronted with great social and political expectations to build Net Zero factories in the spirit of the All Electric Society.

The production process of a car begins with the pressing of the body parts. Metal plates are pressed into special molds to produce the various parts of a vehicle. In further steps, the parts are turned into a ready-to-drive car. The pressing process is a crucial and energy-intensive step in the value chain of an automobile manufacturer. On the one hand, the process lays the foundation for the quality of the end product; on the other hand, failures and delays have far-reaching consequences for the entire production flow and, therefore, the manufacturing costs of the vehicle.

Given the importance of the pressing process, the manufacturer was looking for a solution to detect anomalies in the electric motors of its pressing plants.

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Solution:

Central recording of all motor data and storage in a database with Digital Factory now

With Digital Factory now, Phoenix Contact offers a comprehensive range of products, solutions, concepts, and services for the digitalization of brownfield and greenfield factories, with which resource-saving and competitive digitalized production facilities can be set up. At the center of the portfolio is MLnext, which consists of the software solutions MLnext Creation and MLnext Execution. MLnext enables the simple and effective use of machine learning (ML) in the digital factory. By using anomaly detection, the auto manufacturer can now identify potential problems with the motors at an early stage and act proactively to minimize downtime and ensure product quality (Fig. 2).

Figure 2:
With the framework and the software tools Execution and Creation, the MLnext portfolio offers the right machine-learning solution, which can be downloaded directly from the PLCnext Store.

The first and most important step in any machine learning project is to create a database and baseline. At the manufacturing facility, data from two production lines, each with four presses with electric motors, was recorded for each press shop. This is where another product from the Digital Factory now portfolio comes into play: the IIoT Frameworks. This is a scalable, open, and flexible interface between OT (Operational Technology, production level) and IT (Information Technology). It has connectors for protocols such as Profinet, MQTT, and Modbus that can collect data from the various sensors installed in the heterogeneous OT world. This data can then be stored in a database – such as MySQL or InfluxDB – or in the cloud – such as Proficloud.io, AWS, or Azure – using these connectors. This way, the data is available in a comparable form at all levels at all times (Fig. 3).

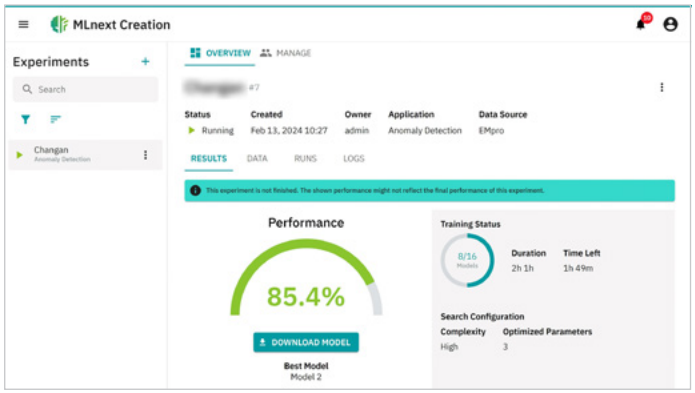

Figure 3:
The open, modular structure enables OT, IT, and the cloud to be connected flexibly and without restrictions.

The manufacturer uses an energy measuring device from Phoenix Contact's EMPro product family to record a motor's electrical parameters. The EMpro records and transmits the motor's power consumption, performance, and other factors via a Modbus/TCP interface. In addition, a combination sensor measures the temperature and vibration and communicates the values via Profinet IO-Link. IIoT Frameworks, which runs on an edge PC from the EPC 1522 series, can collect the data from all motors centrally and archive it in a database. The first database was available after one month.

Simple training of an ML model without programming knowledge

An initial ML model (baseline) was generated using this database. The MLnext Creation software tool provides an intuitive user interface that allows an ML model to be trained without programming or statistical knowledge. The user is guided through the process step by step. The recorded data was imported into MLnext Creation, and the "anomaly detection" application was selected. Finally, the complexity of the hyperparameter search was selected. This determines how many different models are trained and compared with each other until the optimal model is found. The available computing time and computing power prove decisive here. All further steps, such as preprocessing the data, take place in the background (Fig. 4).

The model created by MLnext Creation is a neural network in the form of an autoencoder. This aims to compress the input data and reduce it to the most important features to reconstruct it from this compressed representation subsequently. In anomaly detection, the autoencoder is trained with the motors' normal operating data. If an anomaly is detected in the input data after

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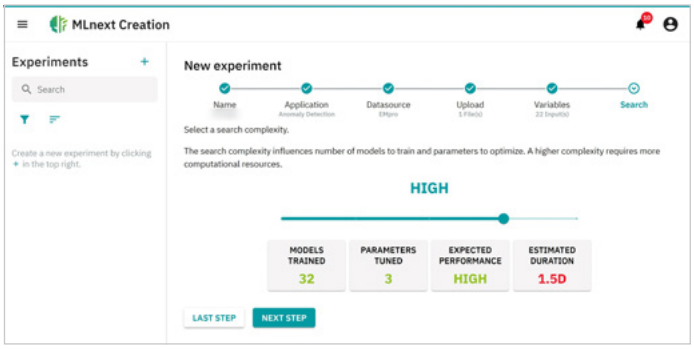

Figure 4:
The MLnext Creation interface is intuitive and uncluttered so that machine learning can be implemented without programming or specialist knowledge.

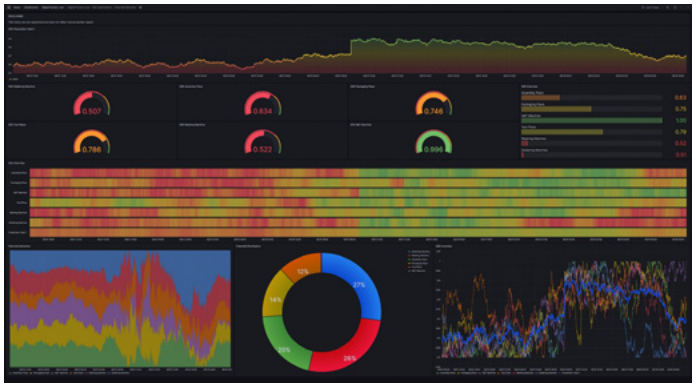

Figure 5:
The Grafana visualization software can be used to create target group-specific dashboards that provide an overview of the most important information.

training, the autoencoder cannot fully reconstruct it. As a result, there are significant deviations between the input data and the reconstructed data so that anomalies can be identified.

Target group-specific creation of customizable dashboards

The next step uses the trained model in the production environment. MLnext Execution offers a configurable pipeline covering the entire process from data acquisition, preprocessing, and inference with the model to storing events. The advantage of MLnext Execution is that no programming knowledge is required either; everything can be set in a configuration file. In the project, MLnext Execution runs on the same EPS 1522 Edge PC that runs the IIoT framework. This allows seamless integration into the existing infrastructure.

The data recorded by the motors is loaded from the database in almost real time and undergoes the same preprocessing as when training the model. The model then analyzes the data for anomalies and archives the results, such as the time period and the trigger, back in the database.

Grafana, a visualization tool, is used to visualize the data and results of the model. Grafana can be used to create target group-specific dashboards that provide an overview of the motors' operating data and the detected anomalies. Grafana also makes it possible for the manufacturer to change the dashboards independently later. Alarms can also be set up to identify anomalies and alert maintenance personnel to potential problems (Fig. 5).

Results:
Continuous improvement of the model

The use of MLnext for anomaly detection in the press shops demonstrates how potential problems can be detected early, minimizing downtime and increasing competitiveness. The process of machine learning also offers the option of continuously improving the model by evaluating the detected anomalies and thus increasing the precision of anomaly detection.

SIDEBAR

Transformation of existing factories into fully digitized production facilities

As the most innovative industry in the world, the automotive industry is under considerable pressure: complex manufacturing processes and high legal requirements pose major challenges. With the Digital Factory now portfolio, Phoenix Contact offers products, solutions and services for transforming existing factories into modern, fully digitalized production facilities in line with the All Electric Society in order to create a sustainable, fully electrified world. The advantages at a glance:

- Holistic approach: Collecting, storing and analyzing data.
- Increased efficiency: Reduced downtime and reduced maintenance workload thanks to data analysis
- No ML expertise required: MLnext enables the use of machine learning without any special prior knowledge, which simplifies accessibility and application in production.
- Adaptability: The solutions can be flexible and applied to different applications with time series data so that they can be used in different production environments.