



All On-Device anomaly detection in NanoEdge AI Studio

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Abstract

This poster presentation discusses the challenges of implementing on-device Machine Learning (ML) for Edge Intelligence (EI) in the industrial field. We introduce NanoEdge AI Studio, a solution developed by STMicroelectronics that allows for All On-Device anomaly detection.

Our solution has various optimizations to make it suitable for the edge, including using zero pre-trained models, incremental training, and adaptability to new environments. We also present the applications of the solution using time-series signals.

On-Device Machine Learning

On-device machine learning (ML), also known as Edge Intelligence (EI), refers to the practice of performing machine learning tasks directly on IoT devices, rather than sending data to a server for processing. This approach has become increasingly important as the number of IoT devices has grown, as it enables more efficient and effective use of these devices. As shown in Figure 1, moving part of Artificial Intelligence closer to the signal brings several benefits, including data security, energy savings, faster inference, cost savings, etc.

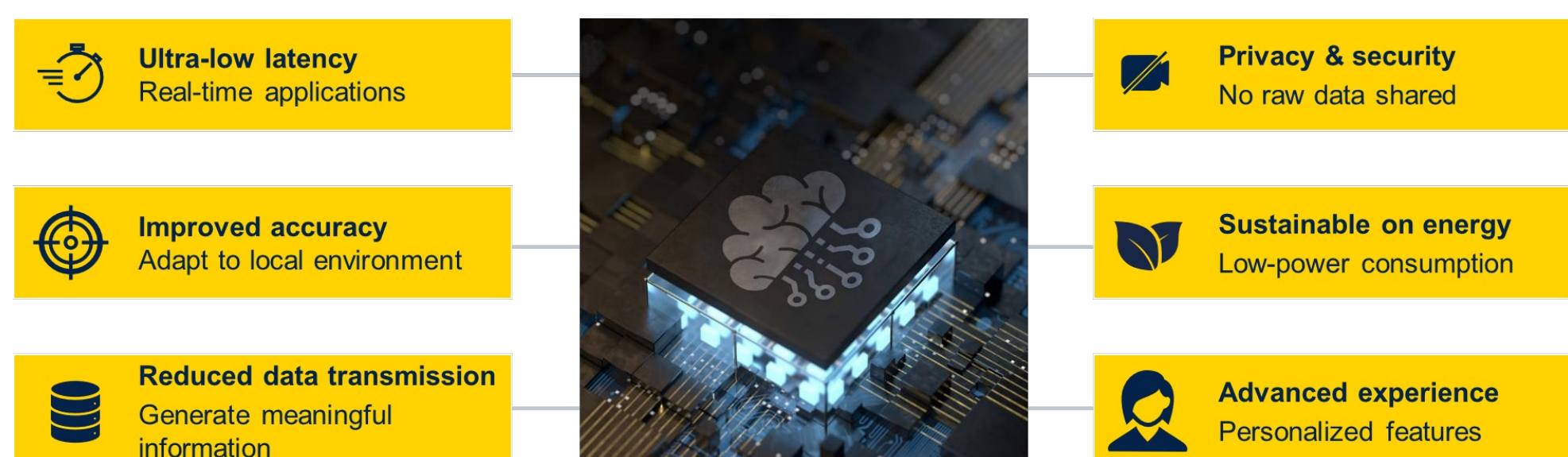


Figure 1: Advantages of Edge Intelligence

On-device models need to be more resource-efficient than traditional ML models designed for servers due to hardware limitations at the edge.

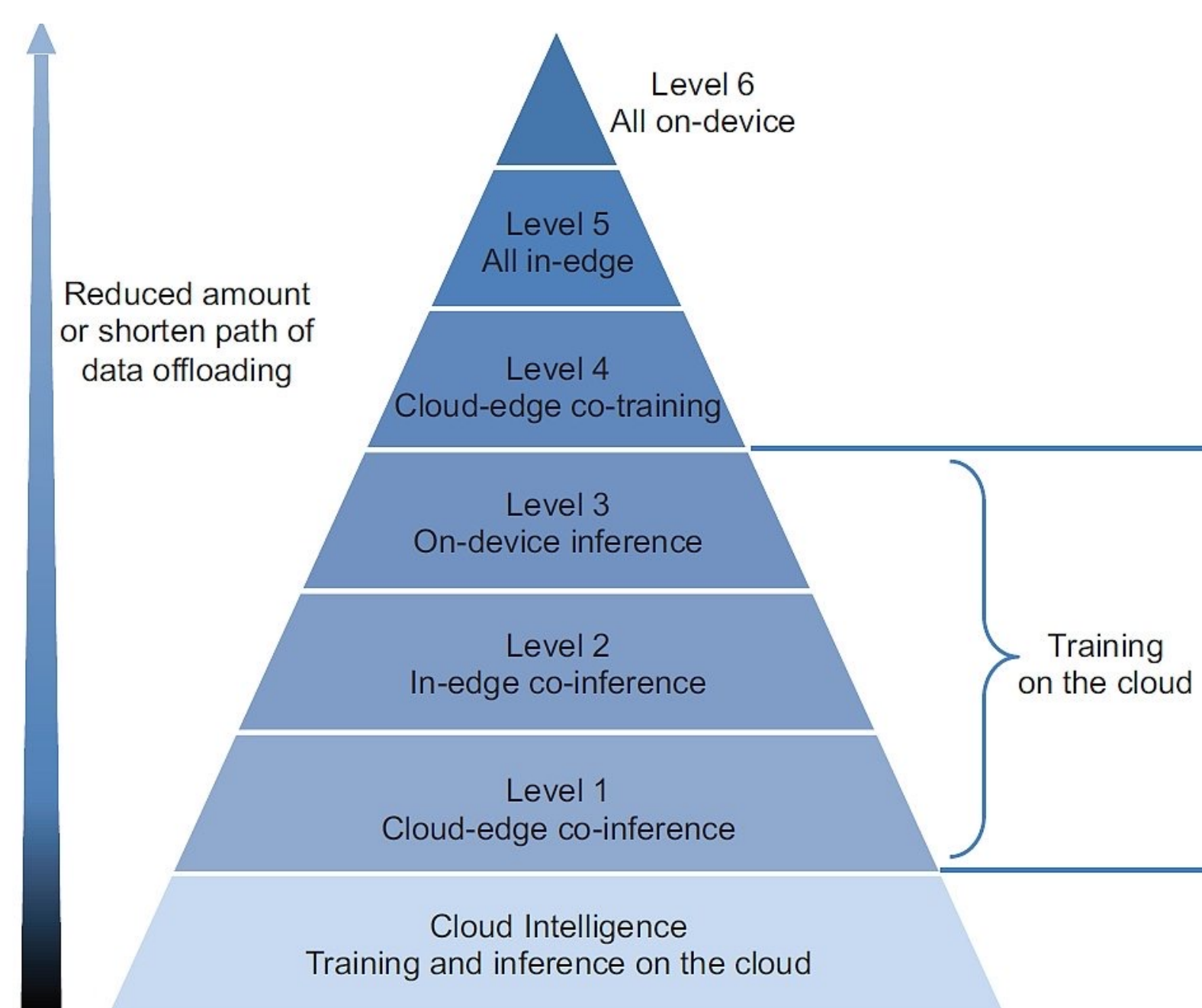


Figure 2: Six-level rating for Edge Intelligence [1]

There are various levels of EI, as shown in Figure 2. Among these, Level 6 All On-Device is the most flexible and independent in terms of resource usage and can maximize the advantages of on-device learning. However, new algorithms and logics need to be developed to suit the All On-Device application.

NanoEdge AI Studio

NanoEdge AI Studio [2] is a user-friendly machine learning software created by STMicroelectronics for embedded developers, designed to simplify the process of ML innovation. As shown in Figure 3, developers can easily create an optimal ML library for their project based on a reasonable amount of data, without the need for advanced data science or AI expertise.

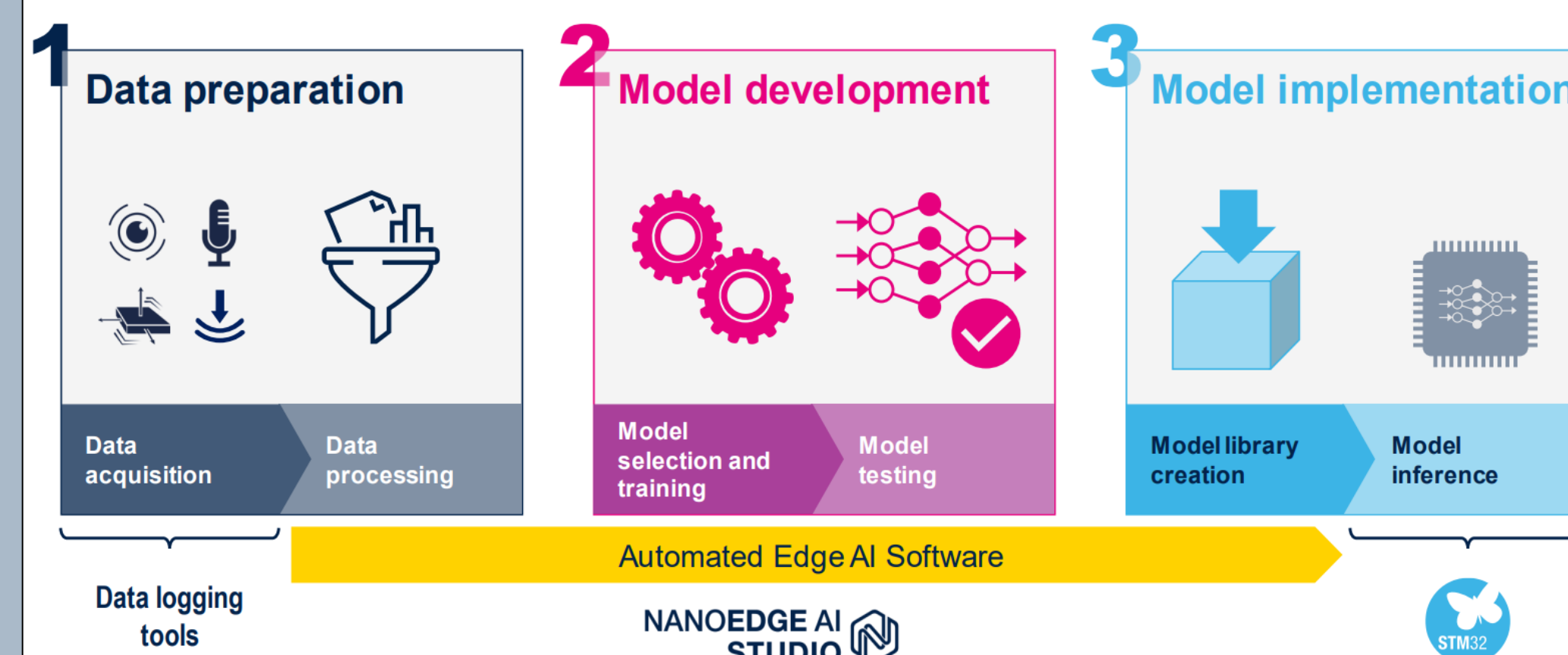


Figure 3: NanoEdge AI Studio in the AI development workflow

To select and optimize ML libraries, the Studio includes a search engine exploring millions of possible algorithms to find the optimal library in terms of accuracy and memory. This process streamlines the AI process, reducing development effort, cost, and time to market. NanoEdge AI Studio can generate very small footprint libraries running on the smallest Arm Cortex-M0 microcontrollers.

All On-Device anomaly detection in NanoEdge AI Studio

The All On-Device anomaly detection solution proposed by NanoEdge AI Studio allows microcontrollers to learn and understand sensor patterns. It gathers knowledge incrementally to become able to detect potential anomalous behaviors.

Our solution has been optimized for real-world industrial applications by incorporating additional criteria, as demonstrated in Figure 4, beyond the basic All On-Device ML guideline.



Figure 4: Additional five criteria for All On-Device anomaly detection solution

Advantages

As shown in Figure 5, for anomaly detection proposed by NanoEdge AI Studio, the model is self-trained at the Edge. The solution is optimized for industrial applications, specifically predictive maintenance, with three main advantages:

- **Autonomy:** The solution enables microcontrollers to learn autonomously, minimizing the need for human intervention.
- **Cost-saving:** The solution eliminates the need for pre-trained models and additional memory, reducing development effort and cost.
- **Flexibility:** The model can adapt to different machines and environments individually and incrementally, increasing the flexibility of application.

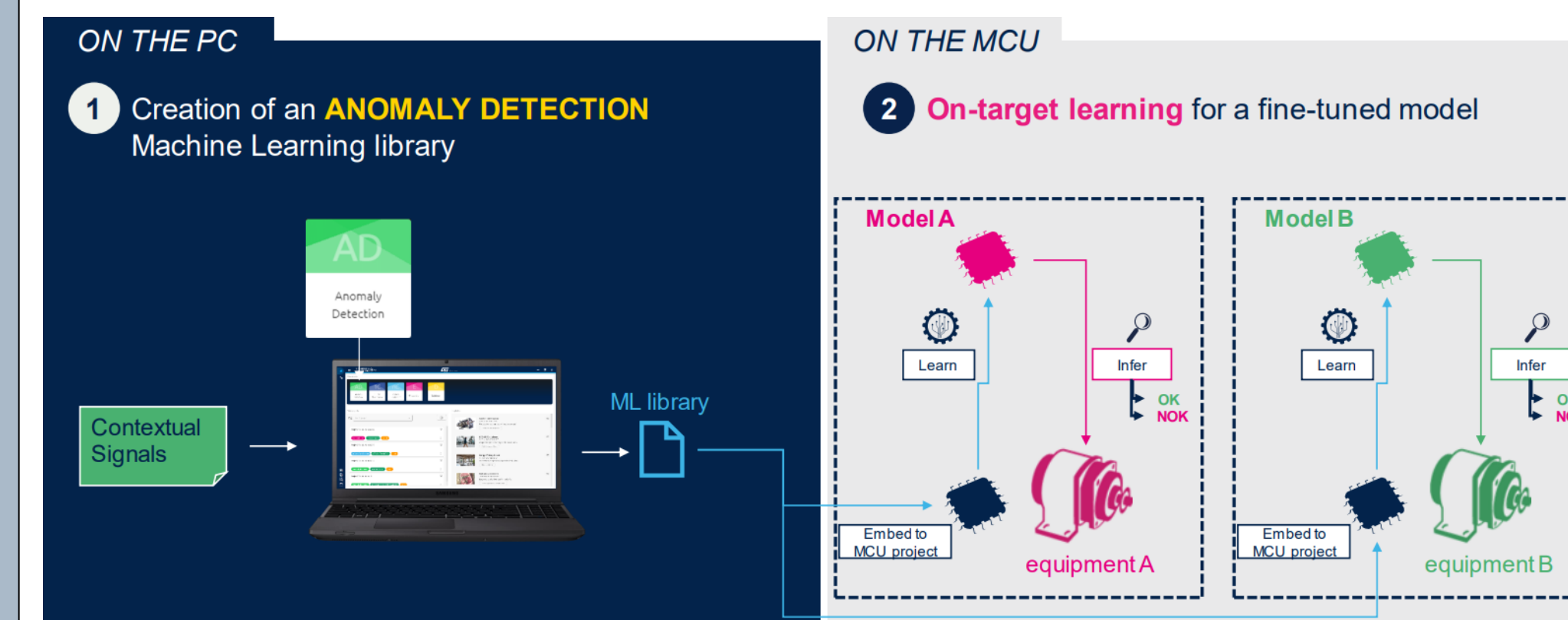


Figure 5: All On-Device anomaly detection solution by NanoEdge AI Studio

Algorithms

The catastrophic forgetting problem occurs when neural networks forget previously learned information when trained on new data, which can be a significant issue in on-device learning scenarios with limited resources. To address this problem, NanoEdge AI Studio has developed alternative algorithms that are better suited for on-device learning while still meeting the criteria listed in Figure 4. We've provided an example flowchart in Figure 6 to show the main processes, as some of these algorithms may have patents associated with them.

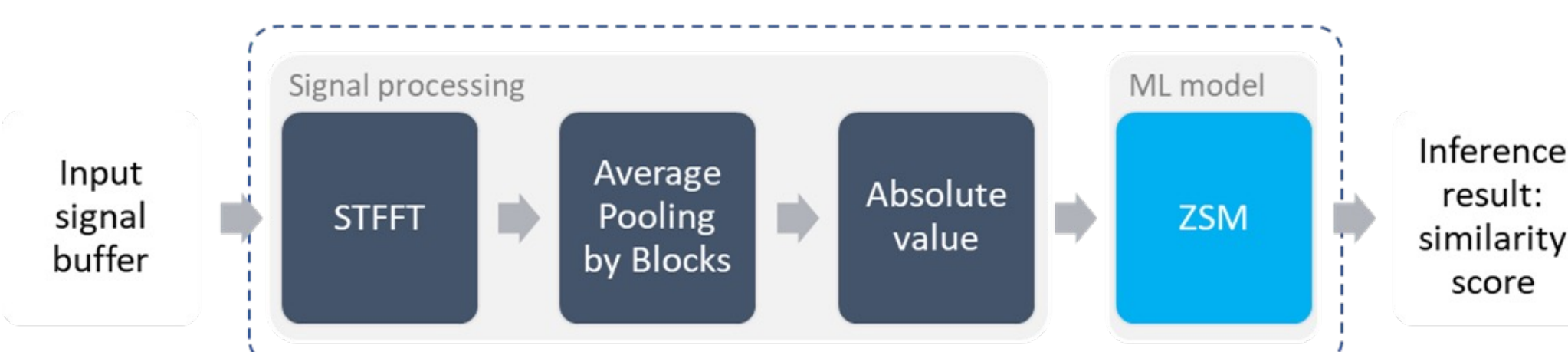


Figure 6: Algorithm flowchart example in All On-Device anomaly detection

In the algorithm flowchart example, the first step involves signal processing, which includes several algorithms chosen by the NanoEdge AI Studio search engine based on the provided dataset. The signal processing algorithms in this example are Short Term Fast Fourier Transformation (STFFT), average pooling by blocks, and absolute calculation. The selection of these algorithms can vary depending on data reference. The second part of the algorithm involves our custom machine learning methods. This method includes Z-Score Method (ZSM), Gaussian Mixture Models (GMM), and Micro Machine Learning (MML). MML is particularly useful for learning different categories of behavior in the model. During the learning process, the model first identifies if the data is in a known category before using it to update its knowledge.

Applications

Figure 7 showcases three demo examples that illustrate how NanoEdge AI Studio's All On-Device anomaly detection capabilities can be applied to various use cases.

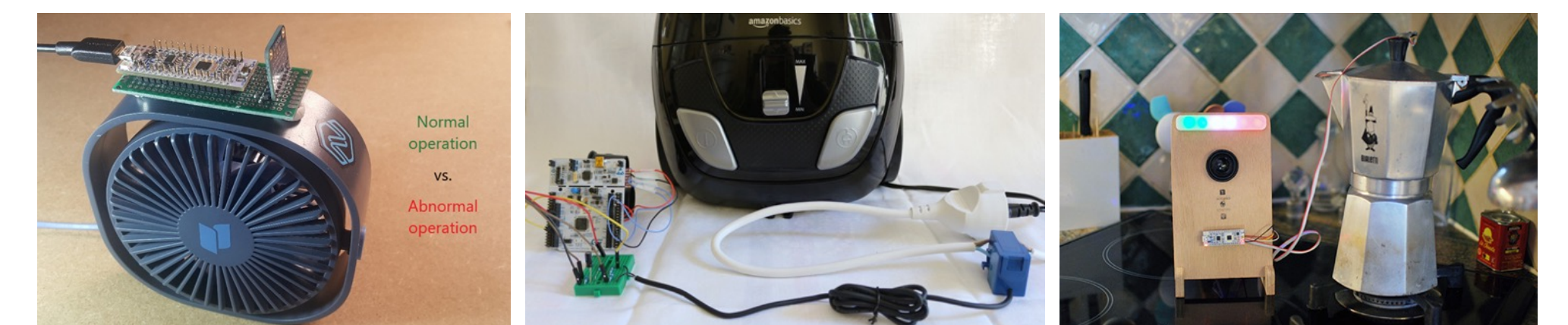


Figure 7: Three demonstrations of All On-Device anomaly detection: Smart Vibration Sensor, Smart Current Sensor and Smart Italian Coffee Watcher

Moreover, this technology has already been successfully integrated into multiple industrial applications, including NKE WATTECO's Bob Assistant application (Figure 8), enabling the monitoring of individual machine health across industries such as manufacturing, automotive, energy, oil & gas, and building & facility management [3].

Application of NanoEdge AI Studio	
Microcontroller	M3 @ 80Mhz
Library Type	Anomaly detection
Signals used	Vibrations
RAM / FLASH	6K / 28K

Figure 8: Bob Assistant application

Conclusion

In conclusion, NanoEdge AI Studio's All On-Device anomaly detection solution offers several benefits, including **autonomy**, **cost saving**, and **flexibility**. The solution is optimized for industrial applications, and alternative algorithms have been developed to address the catastrophic forgetting problem. This technology has already been integrated into various industrial applications and offers a streamlined and efficient way to implement machine learning at the edge.

References

- [1] Z. Zhou, X. Chen, E. Li, L. Zeng, K. Luo and J. Zhang, "Edge Intelligence: Paving the Last Mile of Artificial Intelligence With Edge Computing," in Proceedings of the IEEE, vol. 107, no. 8, pp. 1738-1762, Aug. 2019
- [2] NanoEdge AI Studio - Automated Machine Learning tool for STM32, STMicroelectronics, <https://www.st.com/en/development-tools/nanoedgeaistudio.html>
- [3] Bob Assistant – Artificial Intelligence for Predictive Maintenance, WATTECO, <https://bobassistant.com>