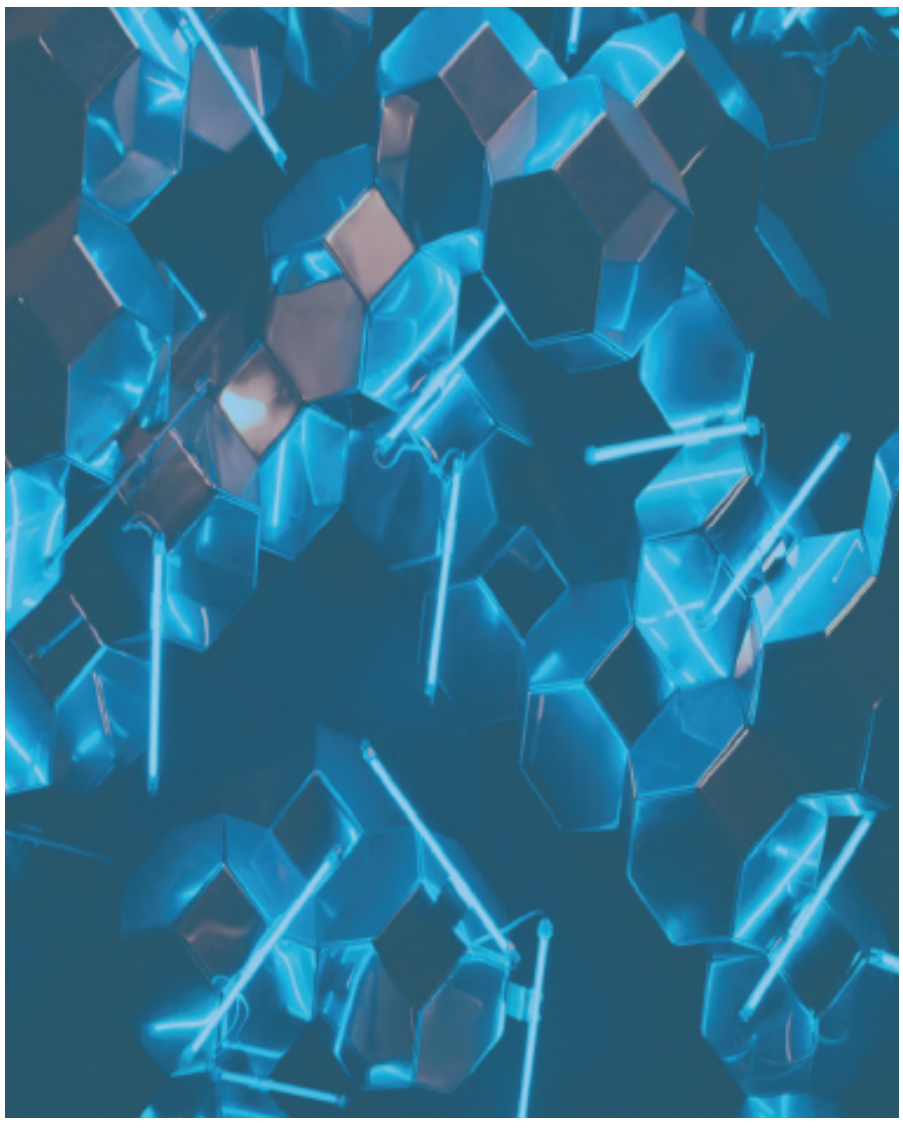
Unlocking Industrial Transformation
with Embedded and Edge AI

By Dr. Phil Marshall, Topio Networks

Executive Summary

Industries across the globe are creating dynamic digital transformation strategies to capitalize on the fourth industrial revolution. These strategies depend on Artificial Intelligence (AI) in embedded and edge computing environments (Edge AI) to harvest, interpret and act upon critical operational information, such as machine data. Machine data is rich in operational information, but notoriously challenging to analyze because of its volume, sparsity and multidimensionality. These challenges are exacerbated by the real-time nature of many of the high value digital services that industrial companies require. MicroAI's MicroAI™ platform addresses these challenges with highly efficient Edge AI capabilities. Its embedded Edge AI has a small compute footprint and self-learning capabilities that can be implemented directly into machines at scale. This solution provides sophisticated intelligence for high value use cases that include condition monitoring, security and anomaly detection and predictive maintenance.



As the fourth industrial revolution continues to become a reality, the stakes are high for embedded system providers, equipment OEMs, software and systems integrators and industrial end users.

As industry players implement embedded Edge AI solutions to harvest machine data and intelligence, integration across machines and other operational technology (OT), as well as between OT and information technology (IT), is needed to maximize business value. This results in Edge AI hierarchies that can potentially span hundreds of machines and systems and depend on machine data derived from embedded Edge AI solutions. However, these hierarchies cannot achieve scalability with point solutions alone. Instead, standardized application programming interfaces (API) are needed among machines and the OT and IT layers in Edge AI hierarchies.

The MicroAI platform incorporates an extensive range of standardized APIs, which Topio believes are particularly well suited for this purpose. in addition, MicroAI enables both AI-training and inference at every layer in an Edge AI-hierarchy. This contrasts conventional Edge AI solutions, which typically have cloud-based AI-training and are limited in their ability to optimize at a machine-level and within the lower layers of Edge AI-hierarchies.

As the fourth industrial revolution continues to become a reality, the stakes are high for embedded system providers, equipment OEMs, software and systems integrators and industrial end users. It is crucial that Edge AI solutions are designed from the outset with future proofed AI environments, which incorporate careful design considerations at the machine level and across OT and IT hierarchies. The right design will enable stakeholders across entire industrial value chains to leverage Edge AI as a key market differentiator.

Introduction

The fourth industrial revolution is upon us, with cyber-physical convergence supported by a range of technologies, including the Internet of Things (IoT), to enable a seemingly endless range of transformative digital services. With IoT and the right analytical tools, machine data and intelligence can be harvested, analyzed and acted upon to yield tremendous operational benefits. These benefits include extended equipment longevity, reduced downtime and optimized operations, and sophisticated capabilities such as condition monitoring, predictive maintenance and enhanced automation. The immense opportunities of the fourth industrial revolution are punctuated by new security threats and attack surfaces that must be addressed as machines become increasingly connected and digitally enabled.

Conventional operational management tools are inadequate for the digital services being developed. Instead, sophisticated Artificial intelligence (AI) is needed to contend with the unique challenges for machines and systems that operate in edge computing environments. This is commonly referred to as Edge AI and is heralding innovative solutions such as MicroAI's MicroAI™ platform, which is discussed in this report.

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Massive Market Opportunities

Edge AI is becoming pervasive as industries pursue digital transformation strategies. Edge AI calls for standardized solutions with the sufficient efficiency, performance and reliability to support a growing range of use cases. Topio forecasts that the global Edge AI hardware and software market will increase from $720 million in 2020 with a 25 percent cumulative annual growth rate (CAGR) to reach $2.2 billion in 2025. Over this time period, Topio forecasts that the percentage of revenues generated by Edge AI software will increase from 45 to 68 percent. The shift in revenue mix in favor of software solutions reflects the anticipated maturation of Edge AI across a growing range of use cases and implementation scenarios.

The industrial use cases that depend on Edge AI are diverse and include:

- **Industrial automation,** which Topio estimates is a $100 to 150 billion global market.
- **Machine condition monitoring**, which Topio estimates is a $3 to 4 billion global market that will see a 7-10 percent CAGR over the next five years.
- **Industrial anomaly detection**, which is particularly applicable to security. Globally, Topio estimates that industrial anomaly detection is a $2 to 3 billion market, with a 15-20 percent forecasted CAGR over the next five years.
- **Predictive maintenance**, which Topio forecasts as a $2 to 3 billion global market, with a 25 percent forecasted CAGR over the next five years.

The business value of Edge AI will increase dramatically in the coming years. As this occurs, it is crucial that stakeholders across entire value chains, including embedded system providers, equipment vendors, systems integrators, solution providers and end users, incorporate Edge AI into their digital strategies and technology architectures.

INDUSTRIAL AUTOMATION

$100-150 billion

GLOBAL MARKET ESTIMATE

MACHINE CONDITION MONITORING

$3-4 billion

GLOBAL MARKET ESTIMATE

7-10% FORECASTED CAGR

INDUSTRIAL ANOMALY DETECTION

$2-3 billion

GLOBAL MARKET ESTIMATE

15-20% FORECASTED CAGR

PREDICTIVE MAINTENANCE

$2-3 billion

GLOBAL MARKET ESTIMATE

25% FORECASTED CAGR

Conquering the Machine Data Challenge

Machine data is at the heart of the burgeoning digital services that underpin the fourth industrial revolution. Conventional data management tools address specific operational tasks, such as machine and plant control, alarm resolution and workflow management.

However, these are a far cry from the transformative digital services that are emerging and depend on machine data, which is:

Voluminous

With individual machines often generating GBytes of data per day, depending on the number of data sources, their resolution and sampling rates.

Sparse

Since most systems have repetitive functions. Sporadic data indicates trending conditions and anomalies that generally have the most value for digital services.

Multifaceted

Where the interdependence between individual machine data streams typically has the most operational relevance, and;

Time Sensitive

Where machine data is most operationally impactful when acted upon in or near real-time.

Edge AI to the Rescue

Since machine data is challenging to harvest using conventional techniques, it is often overlooked in industrial operations. However, this is set to change as digital services take hold and Edge AI solutions demonstrate the tremendous value locked up in machine data. Generic AI solutions will not suffice – instead, specialized tools are needed to efficiently cope with the volume, sparsity and time sensitivity of multifaceted machine data to deliver reliable and actionable operational outcomes.

For example, a digital service that manages the operational integrity of a robotic arm requires a solution to intelligently interpret machine data from multiple sensors and actuators. Normally, a robotic arm will perform reliably and generate voluminous and sparse machine data. An effective AI solution must continuously monitor the robotic arm for normal operations, adapt to the changes in operational conditions and react in near real-time when anomalous operations are identified. Topio believes that this requires an Edge AI solution with a sufficiently small compute footprint for both AI-training and inference to be embedded in the robotic arm.

MicroAI has pioneered its MicroAI platform to deliver the Edge AI performance required for many industrial and commercial applications. The platform delivers AI driven outputs that include alerts on anomalistic behavior and signs of failure, asset health scores, days to next maintenance and predictions for useful life hremaining. Furthermore, the platform efficiently supports the demands of individual machines with its embedded MicroAI AtomML™ and features seamless expandability with its MicroAI Insight™ for anomaly detection and predictive maintenance across potentially hundreds of machines.

As digital services proliferate, Topio believes that Edge AI will become a core requirement for industrial machines and in many respects mirror the past success of IoT. It is important for semiconductor and embedded solution providers and original equipment manufacturers (OEMs) to recognize the strategic importance for incorporating embedded AI in equipment designs from the outset.

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In addition, systems integrators, solution providers and industrial end users all have a vested interest in solutions that are optimized and future proofed for Edge AI, with architectures that are easily integrated into broader digital transformation initiatives.

Edge AI Hierarchies are Needed for industrial Digital Services

The machine data and intelligence harvested from embedded Edge AI has tremendous value beyond the individual machines that are being managed. Data and intelligence aggregated across multiple machines can be acted upon with additional AI capabilities to enhance digital services. Furthermore, when machine data is aggregated across entire industrial facilities, it can support a range of business processes, with key capabilities including sophisticated benchmarking and predictive maintenance to enhance process workflows. For example, a manufacturing facility with multiple production lines might leverage facility-wide predictive maintenance capabilities to redistribute its operations among lines that are better performing, and prioritize the early maintenance of poorer performing equipment.

An AI hierarchy is necessary for industries to fully capitalize on Edge AI and machine data for their digital services. Both embedded and inter-machine Edge AI can be used for a wide range of operational technology (OT) functions, such as automation, anomaly detection and predictive maintenance.

Facility-wide AI, which derives data inputs from potentially hundreds of machines and other operational systems, can support an enormous range of digital services that span both OT and information technology (IT) functions. In some cases, there is value in extending Edge AI solutions to encompass multiple industrial facilities. These solutions might operate on-premises or in managed edge or central cloud environments depending on the digital services being supported.

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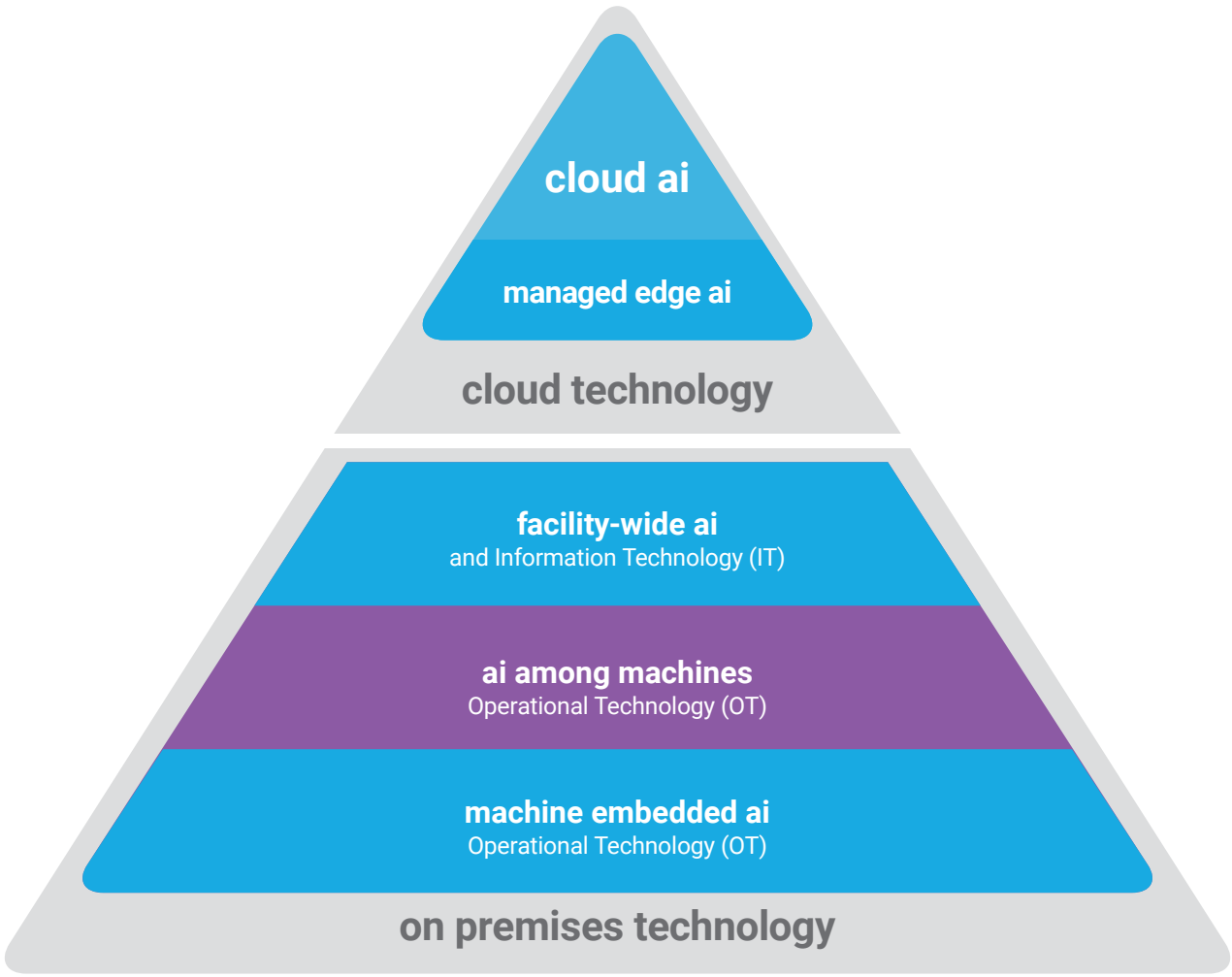


Getting the Edge AI Design Right

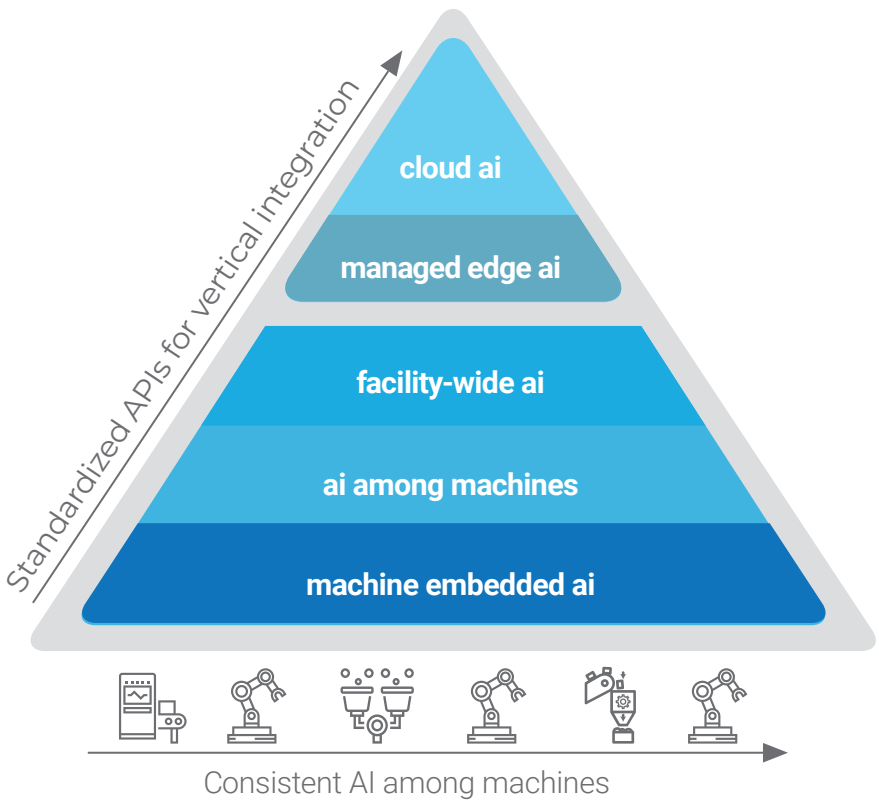
It is easy to lose sight of the subtle characteristics of the AI solutions needed for specific applications. This is particularly evident for Edge AI solutions, which must function and integrate across a diverse range of environments – from machine embedded systems with small compute footprints to high performance on-premises equipment, and in some cases, managed edge and cloud environments.

Key Edge AI requirements include the following:

- Scalability and flexibility to support both current and future machine operations and optimization demands.
- Standardized and extensible APIs for managing the flow of data and intelligence, and;
- Solutions that anticipate hierarchical Edge AI architectures with OT/IT integration to support emerging digital services and transformation strategies.

The unique demands for machine embedded Edge AIembedded Edge AI

In contrast to conventional AI solutions, which typically depend on large datasets and extensive cloud based computing power for AI-training, machine embedded Edge AI solutions must operate effectively within relatively modest compute footprints. Solutions incorporated in machine designs from the outset generally deliver superior performance, enabling embedded systems and OEM hardware providers to offer differentiated solutions. However, these AI solutions must also support retrofitted implementations to parallel machine embedded Edge AI. Topio believes that retrofits will likely continue to be used for the foreseeable future. Most installations cannot support extensive supervised AI model training. Instead, the solutions must incorporate largely unsupervised AI learning algorithms and contend with the underlying challenges associated with machine data, including volume, spasticity, multidimensionality, and real-time relevance.



The Edge AI Hierarchy

As industrial companies advance their digital services, they will increasingly depend on operational intelligence and insights throughout their entire enterprise. This is punctuated by the need for integration among OTs as well as between OT and IT ecosystems.

Historically, OT and IT ecosystems have been siloed. As these silos are disrupted by emerging digital services, it is crucial to minimize technical integration challenges and ensure that tangible business value can be attained with ease. This has direct implications for the Edge AI functionality needed throughout the entire hierarchy of a typical implementation. Embedded Edge AI solutions must be consistent among machines and carefully architected to deliver business value from the harvested machine data and intelligence. AI point solutions will not suffice – instead, standardized interfaces are needed to enable OT and OT/IT integration that emerging digital services require.

Selected Industrial Edge AI Use Cases

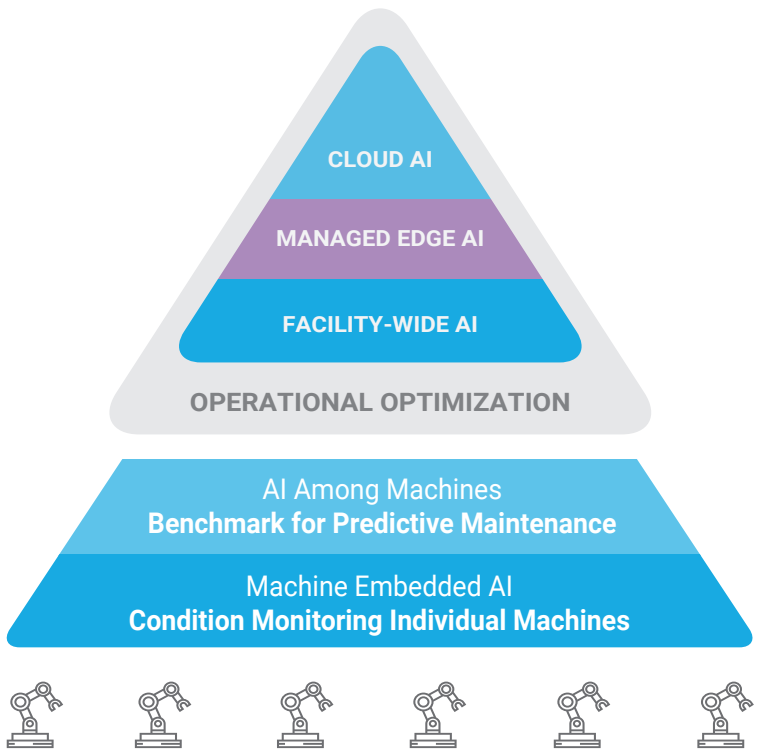
As digital services mature, the breadth of industrial Edge AI use cases will increase dramatically in the coming years. This will require greater intelligence, insights and operational agility from the underlying systems involved. In addition, with OT/IT integration, Edge AI will take on a variety of roles depending where in the hierarchy the AI resides, whether embedded in the machine, at a machine aggregation layer, facility-wide or across multiple facilities. Several selected use cases are summarized below to illustrate practical Edge AI applications.

Use Case: Robotic Arm Condition Monitoring

Industrial robots have been used for decades in manufacturing, particularly for highly deterministic applications,such as spot welding. In recent years, advances in key technologies including Edge AI, have enabled more sophisticated and dynamic industrial robotic use cases, such as bin picking and collaborative and autonomous mobile robots. Even simple industrial robots such as robotic arms are challenging to intelligently manage and monitor due to the variety of machine data that must be analyzed in real-time. In the case of a robotic arm, the machine data spans a large number of sensor and actuator measurements from the arm itself, as well as external sources that indicate other operational and environmental conditions (e.g. line speed, ambient temperature and humidity). Since individual machine data inputs are interdependent and can vary under normal operating conditions, it is not sufficient to monitor each input in isolation. For example, a robotic arm operating in a noisy environment is likely to have a different vibration condition monitoring profile than an equivalent robotic arm in a less noisy environment. In addition, since the machine data is voluminous and sparse and requires real-time analysis, it is ideally suited for an embedded Edge AI solution.

MicroAI has deployed its MicroAI platform to successfully enable intelligent condition monitoring and anomaly detection for robotic arms. This Edge AI platform capitalizes on MicroAI AtomML™ and MicroAI Insight™ solutions, with an emphasis towards the following:

- A small compute footprint so that Edge AI training and inference can be embedded directly into the robotic arm;
- Learning algorithms, which are largely unsupervised and can cope with dynamic operating conditions;
- An efficient exception handling mechanism to cope with voluminous and sparse data to support real-time condition monitoring and anomaly detection demands; and
- Standardized APIs so that the machine data and intelligence can be integrated among machines to support benchmarking and predictive maintenance capabilities and integrated facilitywide to support operational optimization initiatives.



Use Case: Manufacturing Production Workflow Management

It is common for manufacturing facilities to have duplicate machines and parallel production lines to meet their output demands.

Effective Edge AI hierarchies for condition monitoring and predictive maintenance enable manufacturers to benchmark and estimate the relative condition of their production lines. With this intelligence, workflows can be prioritized to high performing production lines.

This relieves capacity on poor performing production lines so that maintenance activities can be prioritized.

Since operational workflow solutions typically incorporate IT functions, this use case is an example of OT/IT integration, where AI derived machine data and intelligence has the potential to create tremendous business value for a manufacturer or other industrial company with duplicative infrastructure.

MicroAI's MicroAI AtomML™ and MicroAI Insight™ platforms incorporate standardized APIs to expose machine data and intelligence to higher level OT and IT systems, including operational workflow management systems.

Use Case: Securing Smart Meters

Smart meters commonly operate in hostile environments and are vulnerable to large security attack surfaces. Since bad actors are continually evolving their attack strategies and are attracted to large-scale systems such as smart meters, it is not sufficient to implement static security solutions that only address known vulnerabilities.

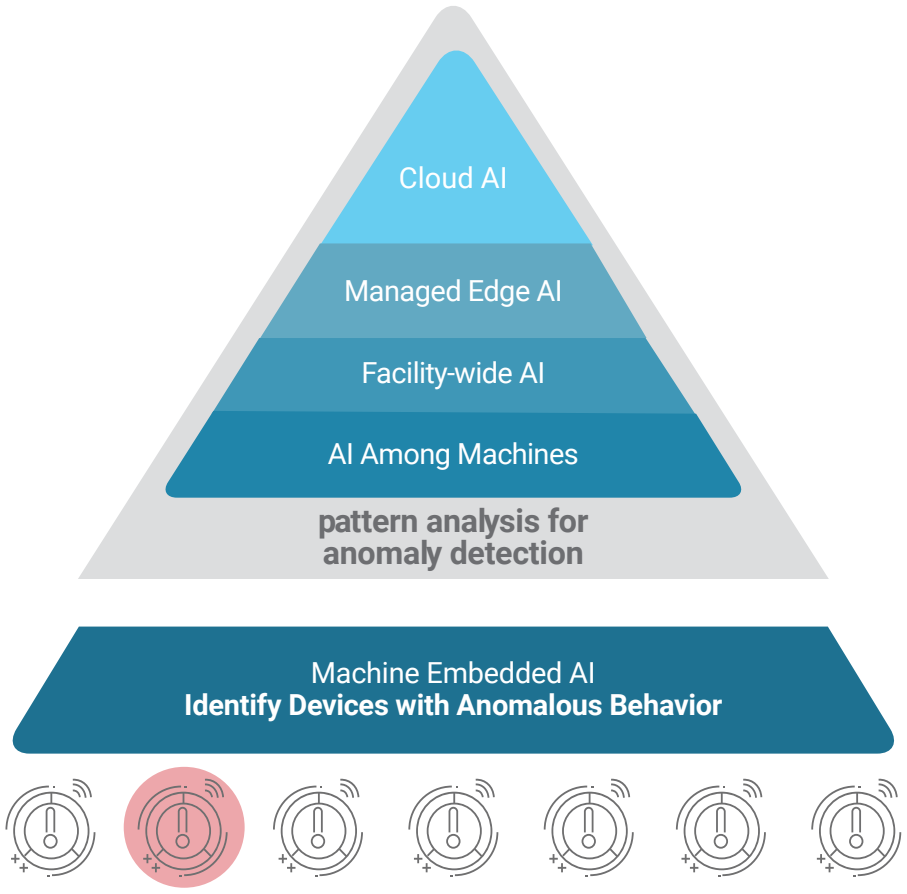
Smart meters are particularly vulnerable to zero-day attacks, which can potentially go undetected for extended periods of time and wreak havoc on adjacent systems.

This has led to vibrant innovation with AI techniques that are well suited to the MicroAI platform, which learns and continuously adapts to normal operational conditions and rapidly identifies anomalous behavior.

This behavior can be continuously monitored in individual meters using the embedded MicroAI AtomML™ solution and with pattern analyses among many meters using standardized APIs and the MicroAI Insight™ solution to enhance anomaly detection and security protection capabilities.

Conclusions and Recommendations

Machine data and intelligence provides tremendous operational value to industrial companies, particularly those that pursue digital transformation initiatives. Since machine data is typically voluminous, sparse, highly interdependent and time sensitive, valuable data insights cannot be leveraged using traditional operational data management platforms. Instead, embedded Edge AI solutions that can efficiently harvest, analyze and act upon machine data are needed. In order to achieve the performance and scalability demands of typical industrial environments, these embedded solutions require compact compute footprints and extensive selflearning capabilities. Machine data and intelligence gleaned from embedded Edge AI systems provide valuable operational insights across a broad range of digital services – spanning multiple machines, other industrial systems and even entire facilities.



Many conventional Edge AI solutions rely on centralized cloud computing resources for AI-training.

This creates the need for Edge AI hierarchies which allow for the aggregation and flow of data and intelligence among different OT and IT functions within industrial environments. However, this cannot be achieved solely with Edge AI point solutions. Instead, standardized APIs, such as those incorporated in MicoAI's MicroAI platform, are needed to expose data and intelligence, within individual machines, and among machines, and other OT as well as between OT and IT systems. Many conventional Edge AI solutions rely on centralized cloud computing resources for AItraining. Topio believes that this approach is suboptimum since it does not address the salient characteristics of individual machines and operating facilities. MicroAI's MicroAI addresses these challenges to enable greater performance by enabling both AI-training and inference capabilities throughout Edge AI-hierarchies including embedded Edge AI in individual machines.

The strategic importance of Edge AI provides opportunities for embedded system providers, equipment OEMs, systems integrators and end users to differentiate their offerings based on the AI functionality that they enable. However, to achieve sustained differentiation, it is crucial that these players incorporate Edge AI capabilities in their solution designs from the outset rather than retroactively. The players who recognize the strategic importance of Edge AI will be well positioned to capitalize on the burgeoning digital services that will fundamentally transform industries over the coming decade.

To accelerate markets and businesses, Topio Networks offers detailed data insights and natural language analysis about the shape, structure and sizing of the thousands of use cases, verticals and technologies that are the building blocks of the fourth industrial revolution. Our data is constantly fed by the daily insights generated by our taxonomy driven, human curated AI Platform. The Topio Networks Market Intelligence Center provides free access to our industry research with detailed data about market sizing, innovations, funding and marketing activities for each specific use cases, industries and emerging technologies.

In addition, Topio Networks offers acceleration services to businesses by providing the content necessary to develop their go to market strategies, by tracking the company content and mapping it to the best practices of the industry and providing market access through events and lead generation.

To learn more about how Topio Networks applies AI and Natural Language Processing to create comprehensive research about thousands of use cases,

About Topio Networks

Topio Networks, an industry research platform, accelerates markets and businesses by providing detailed information about use cases, verticals and industries. By leveraging our open platform, businesses can benefit from meaningful data insights, market feedback & surveys, and information about the effectiveness of their company thought leadership. In addition, Topio Networks provides market access through events, and lead generation.

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