WHITE PAPER

The Artificial Intelligence of Things

From smart connected devices to artificially intelligent things, services and experiences

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Some technologies are inevitably bound together. Artificial intelligence (AI) and the Internet of Things (IoT) are a perfect example of two technologies that complement one another and should be tightly connected.

In the fast-growing world of IoT, which connects and shares data across a vast network of devices or "things," organizations win with analytics. For its ability to make rapid decisions and uncover deep insights as it "learns" from massive volumes of IoT data, AI is an essential form of analytics for any organization that wants to expand the value of IoT.

In this paper, we'll explore how AI and IoT analytics (that is, the artificial intelligence of things, or AIoT) work together to create new value for organizations across a broad spectrum of industries – from manufacturers and retailers to energy, smart cities, health care and beyond.

"If analytics is a requirement for success in IoT, is analytics in the form of AI a necessity for IoT to fulfill its potential? Is the artificial intelligence of things – AIoT– the ultimate success story of the Internet of Things?"

– Oliver Schabenberger, Executive Vice President, Chief Operating Officer and Chief Technology Officer, SAS

The Meteoric Rise of Connected Things

In 1982, a modified Coke machine at Carnegie Mellon University became the first connected smart appliance, able to report its inventory and whether newly stocked drinks were cold. Fast forward a few decades, and we are living in a world where there are more connected things than humans. Business Insider Intelligence projects that there will be more than 55 billion IoT devices by 2025, up from about 9 billion in 2017.[1]

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The rapidly expanding Internet of Things extends connectivity and data exchange across a vast network of portable devices, home appliances, vehicles, manufacturing equipment and other things embedded with electronics, software, sensors, actuators and connectivity. From consumer wearable devices to industrial machines and heavy machineries, these connected things can signal their environment, be remotely monitored and controlled – and increasingly, make decisions and take actions on their own.

IoT is everywhere. It's a home automation system that detects changing conditions and adjusts the thermostat or lighting. It's production equipment that alerts maintenance technicians to an impending failure. Or an in-vehicle navigation system that detects your location and gives you context-aware directions. Digital personal assistants that use speech recognition to interpret commands. Commercial fleets equipped with dozens of sensors to communicate their status. And much more.

This ecosystem of connected devices, people and environments generates a torrent of complex data. For instance, today's cars and trucks are like data centers on wheels, equipped with sensors that can monitor everything from tire pressure to engine performance, component health, radio volume, driver actions – even the presence of obstacles or rain on the windshield. A connected vehicle puts out around 25GB of data per hour.[2] Autonomous, self-driving vehicles may put out as much as 1GB of data per second.

By 2022, more than 80 percent of enterprise IoT projects will have an AI component, up from less than 10 percent today.[3]

However, being connected and exchanging masses of data is only the start to the IoT story.

1 IoT Report: How Internet of Things Technology Is Now Reaching Mainstream Companies and Consumers. By Peter Newman. Business Insider. July 27, 2018.

2 How Much Data Does Your Car Collect? More Than You Think. By Gordon Hunt. Silicon Republic.

3 Gartner, Inc. Forecast: The Business Value of Artificial Intelligence, Worldwide, 2017-2025. By John-David Lovelock, Susan Tan, Jim Hare, Alys Woodward, Alan Priestley. March 12, 2018.

Transforming IoT Data Into Business Value

Organizations that can capture IoT data and transform it into insight using real-time AI will see real business value:

- Greater efficiency and productivity as AI makes complex decisions and automates manual tasks.
- Cost reductions as AI optimizes processes to reduce marginal transaction costs.
- Higher profitability – as much as a 38 percent lift by 2035, according to Forbes.[4]
- Faster innovation life cycles, as AI makes it easier for organizations to start, scale and grow their operations.
- Better products and faster customer service, such as bots powered by speech recognition.
- Faster time to market by reducing complexity and enabling continual experimentation.

[4] Artificial Intelligence Will Enable 38% Profit Gains by 2035. By Louis Columbus, contributor. Forbes.

From Collecting Data to Collective Learning

A smart, connected device is made up of four layers:

- Physical elements such as the mechanical and electrical parts.
- Smart elements such as sensors, processors, storage and software.
- Connectivity elements such as ports, antennas and protocols.
- Onboard analytics, in some cases, to train and run AI models at the edge.

The physical components are amplified by the smart elements. The smart elements are in turn amplified by connectivity, which enables monitoring, control and optimization. But by itself, connecting things does not promote learning. It paves the way, but that's just the foundation.

At the most basic level, the data generated from IoT devices is used to trigger simple alerts. For example, if a sensor detects an out-of-threshold condition, such as excessive heat or vibration, it triggers an alert and a technician checks it out. In a more sophisticated IoT system, you might have dozens of sensors monitoring many aspects of operation.

All these scenarios add value to and from connected devices. But the real value of IoT comes at yet another level of sophistication. It happens when devices learn from their specific use or from each other and then automate actions. It happens when they can adapt, change behavior over time, make decisions, take action and tune their responses based on what they learn.

For example, a model using IoT data to detect failures can push machine controls to the appropriate IoT powered actuators to reduce the possibility of failures on similar equipment. Self-driving vehicles can transmit their experiences to other cars in the network.

These capabilities are the basis for the personalization required of IoT applications:

- **As humans**, we want to be treated individually and know that our habits, behavioral patterns and preferences are considered. For instance, think about a consumer wearable technology that monitors movements to detect signals of an impending injury in an athlete. No two humans move the same, so the application would only be meaningful with great personalization.

  For another example, retailers use IoT-enabled cameras for object detection along with machine learning to deliver tailored advertisements and offers to shoppers at the right moment.

- **As machines** become more complex, they need personalization too. Two pieces of industrial equipment of the same make and models do not perform identically under different conditions and might not be used in the same way. Treating them alike misses IoT opportunities for greater operational efficiency, greater safety and better use of resources.

  For example, machine learning is leading to better decisions on the plant floor by helping operators determine the best possible collection of machines for a specific production run.

The real value of IoT happens when devices learn from their specific use or from each other and then automate actions.

Here's Where Artificial Intelligence Comes In

AI is the science of training systems to emulate human tasks through learning and automation. With embedded AI, machines can learn from experience, adjust to new inputs and accomplish specific tasks without manual intervention. Facial recognition, speech recognition and beating chess champions at their own game – these are all applied uses of AI.

AI has been around since the 1950s, but it is really finding its place in mainstream applications as a result of the explosion in IoT data volume, high-speed connectivity and high-performance computing.

Today, AI uses a variety of statistical and computational techniques. Machine learning, a subset of AI, identifies patterns and anomalies in data from smart sensors and devices, without being explicitly programmed where to look. Over time, machine learning algorithms "learn" how to deliver more accurate results. As such, machine learning outperforms traditional business intelligence tools and makes operational predictions many times faster and more accurately than systems based on rules, thresholds or schedules.

Deep learning, computer vision, natural language processing, and machine learning in time-tested forecasting or optimization – technologies such as these make AI an essential complement to IoT. AI separates signal from noise, giving rise to advanced IoT devices that can learn from their interactions with users, service providers and other devices in the ecosystem.

We should be thinking less about the Internet of Things, and more about the Intelligence of Things. We need to infuse analytics into our systems and applications, because collecting data alone is not enough.

Randy Guard,
Executive Vice President and
Chief Marketing Officer, SAS

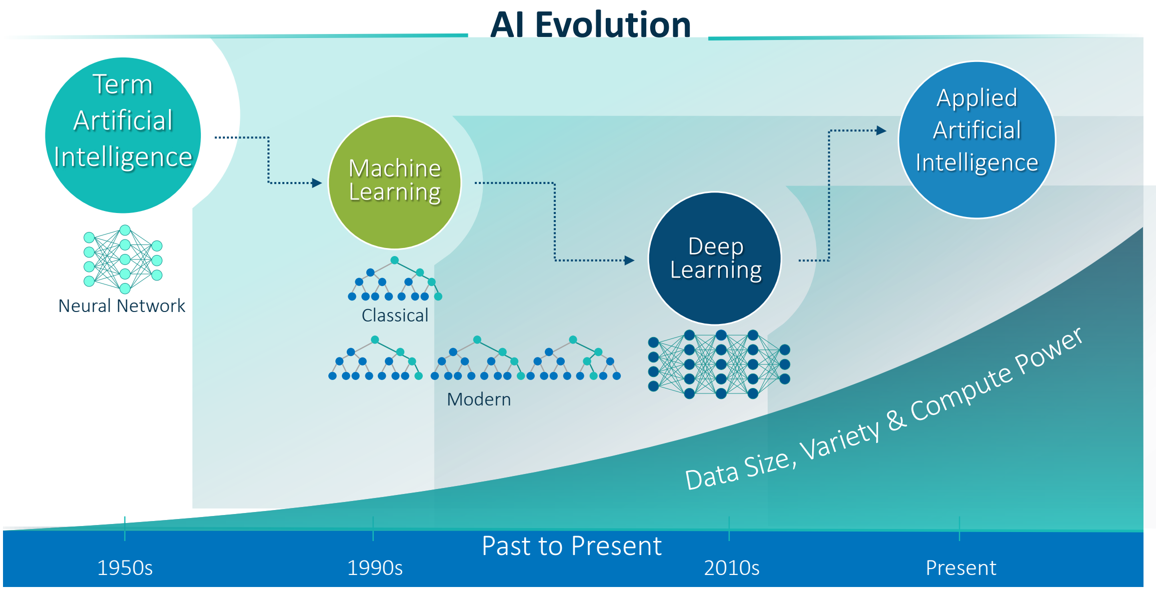

Figure 1: The evolution of artificial intelligence.

The Potential of AI and the Intelligence of Things

AI-powered connected smart devices and environments learn from a greater network of data sources (including each other) and contribute to collective intelligence. There are numerous examples across industries that illustrate this potential:

- **Utilities and manufacturers** can detect underperforming assets and predict the need for maintenance or automated shutdown before costly or hazardous equipment failures occur.
- **Digital twins** are virtual simulations of real-world things such as airplane engines or wind turbines outfitted with sensors. They enable engineers and operations personnel to analyze the performance of equipment in the field while minimizing the costs and safety concerns of traditional testing methods.
- **Retailers** can use location-based and context-aware technologies to detect in-store behavior, combine it with other data such as online user profile and in-store inventory, and send real-time personalized offers while the customer is in the store.
- **Drones** can comprehend unknown surroundings on the fly – even in dark, obstructed environments beyond the reach of internet or GPS – to investigate hazardous areas such as offshore operations, mines, war zones or burning buildings.
- **Robotic platforms** travel the aisles of a warehouse, picking parts or goods off the shelf and delivering them to the right place, avoiding collisions along the way. Collaborative robots ("cobots") work alongside humans to do heavy lifting, stage materials for assembly or complete repetitive tasks and motions.
- **Shipping containers and tractor-trailers** can monitor conditions such as temperature, humidity, exposure to light, weight distribution, and CO^2 and oxygen levels to maintain the integrity of loads and speed delivery and check-out.
- **Remote monitoring devices** provide at-home diagnostics, alert caregivers when intervention is needed, and remind patients to take their medications.
- **Cities** can deploy connected sensors into the physical infrastructure to constantly monitor for energy efficiency, air pollution, water use, traffic conditions and other quality-of-life factors.

Artificial intelligence can multiply the value of IoT by using all the data from smart devices to promote learning and collective intelligence.

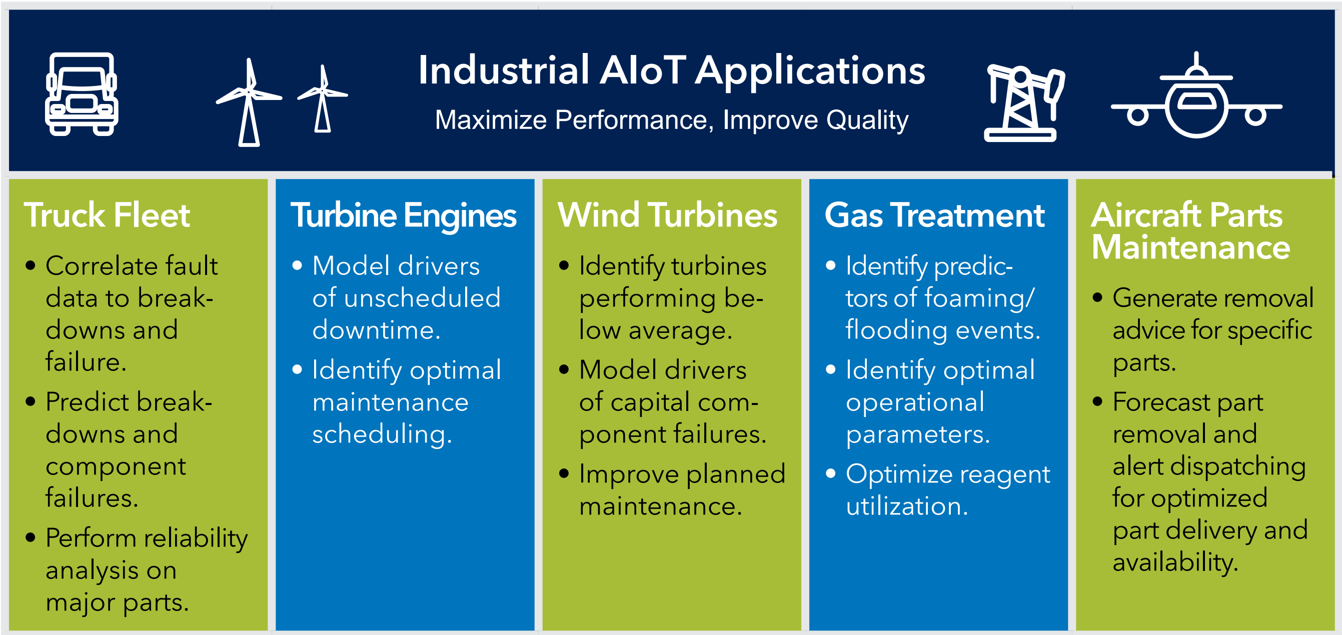

Figure 2: Industrial AI-driven IoT applications.

If we can train an algorithm to suggest the next best move in the complex game of Go (we can), we can train an algorithm to adjust the chillers in a data center or the blade angle of a wind turbine, or to dispense the right amount of medicine at the right time.

This adaptive, predictive and "learning" capability is particularly important in the Industrial Internet of Things (IIoT) because there is so much at stake where system failures and downtime can result in life-threatening or high-risk situations.

Bringing Advanced Analytics to the Edge

Where analysis of IoT data takes place depends on issues of bandwidth and latency:

- For applications that can tolerate some delay or are not bandwidth-intensive, such as approving an online loan application, the IoT device sends data to the cloud or data center, which analyzes it in light of historical performance and other trends, and then applies the insights, possibly to push a decision or modified logic back out to the devices.
- For cases where mobile or remote assets churn out lots of data that must be analyzed quickly – such as self-driving vehicles or drones – or where bandwidth is constrained, data processing is moved as close to the data source as possible – to the edge.

With AI-powered capabilities, IoT data can be transformed, analyzed, visualized and embedded across the entire ecosystem – edge devices, gateways and data centers, in the fog or in the cloud.

The Industrial Internet of Things

A primary objective in IIoT is to automatically monitor and detect shifts in telemetry and sensor data to spot deviations from normal performance and prevent downtime or catastrophic failure. AI is already proving its value in commercial fleets, wind turbines, aircraft maintenance and utility generation.

AI and IoT in Action

Smart Copiers and Printers Report When They Need Service or Supplies

Konica Minolta Japan is the distributor and service provider arm of Konica Minolta Inc., which primarily manufactures office equipment such as copiers and digital print systems.

Historically, the company kept each customer supplied with three spare toner cartridges per unit. But sometimes customers didn't want the toner taking up their office space, or they would discard the toner without using it because its expiration date had passed.

After adopting AI with connected sensors on the copiers and printers, Konica Minolta Japan was able to track consumption of toner and send replacement toner cartridges when needed. Combining data from the devices with external data and applying machine learning, the company generates forecasts that enable just-in-time delivery for better customer satisfaction.

Konica Minolta Japan also uses data from remote sensors to establish proactive maintenance. The company now forecasts the life of parts based on the status of use and sends service personnel to the customer before a problem develops.

Soccer Player Selection Goes High-Tech With AI

Football. Soccer. Whatever you call it, the world's most popular sport is being transformed by a Dutch sports analytics company bringing AI to the game. SciSports uses streaming data and applies machine learning, deep learning and AI to capture and analyze this data for a variety of uses, from player recruitment to virtual reality for fans.

Traditional football data companies only generate data on players who have the ball, leaving everything else undocumented. This leads to an incomplete picture of player quality. Seeing an opportunity to capture the immense amount of data happening away from the ball, SciSports developed a camera system called BallJames.

BallJames is a real-time tracking technology that automatically generates three-dimensional digital images and data from video. Fourteen cameras placed around the stadium record every movement on the field. BallJames then generates data such as the precision, direction and speed of the passing, sprinting strength and jumping strength. The result is a much more comprehensive view of players.

Machine learning algorithms calculate the quality, talent and value of more than 200,000 players in more than 1,500 matches a week in 210 leagues. This analysis helps clubs find talent, look for players that fit a certain profile and analyze their opponents.

To accurately compile 3D images, BallJames must distinguish between players, referees and the ball. SAS® Event Stream Processing enables real-time image recognition and analysis using deep learning models. "By combining our deep learning models into SAS® Viya®, we can train our models in-memory in the cloud, on our cameras or wherever our resources are," says Wouter Roosenburg, SciSports Chief Technology Officer.

> "The SciSkill Index evaluates every professional football player in the world in one universal index. Our ambition is to bring real-time data analytics to billions of soccer fans all over the world. By partnering with SAS, we can make that happen."
>
> – Giels Brouwer, Founder and CEO, SciSports

Protecting Endangered Species, One Footprint at a Time

Nonprofit research organization WildTrack monitors endangered species to understand how best to protect them and reduce human-wildlife conflict. Traditional methods using radio collars and observational surveys were costly, stressed the animals and put researchers in danger.

WildTrack knew there had to be a better way. Much could be learned by monitoring the animals' footprints and coding the expertise of indigenous trackers into sophisticated AI algorithms.

WildTrack's footprint identification technique (FIT) was developed with the help of bushmen trackers in southern Africa. From digital images of footprints tagged with date, time, location and other information, FIT can identify the species, individual, age-class and gender of an animal. Their tracks tell a collective story that holds significant value in conservation efforts.

The only equipment needed is a digital camera, GPS unit (for field location), a scale, and either voice-tag or pen and pencil. Local community members photograph the footprints. The FIT process converts that footprint into a geometric profile and analyzes it for classification.

Given enough data, a computer can be trained to accurately identify footprint images and recognize patterns, simulating the methods used by expert trackers, but with the added ability to apply these concepts quickly at large scale. Analytics underpins the whole process, giving insights into species populations that WildTrack never had before.

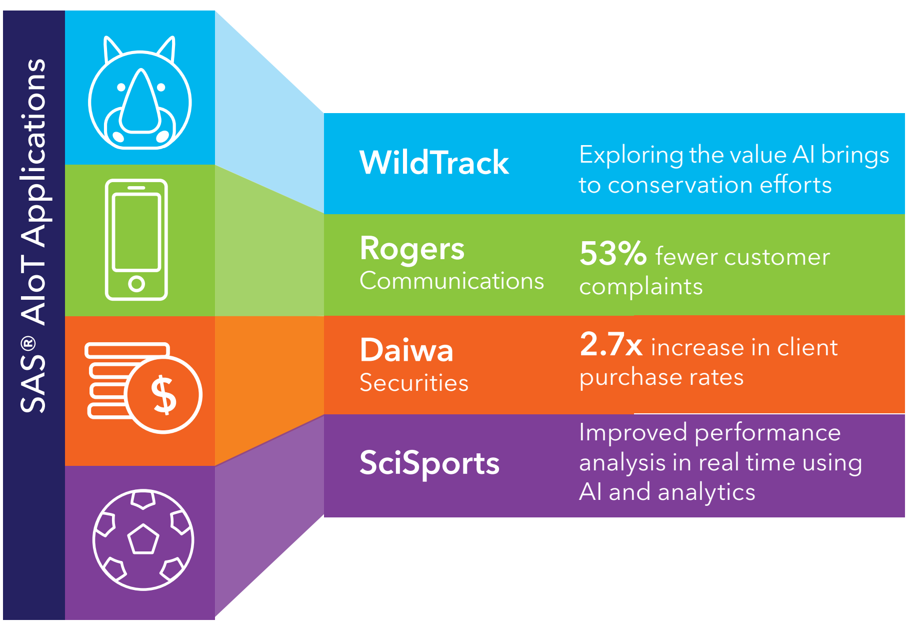

Figure 3: Fueled by IoT data, AI delivers substantial business benefits.

IoT Data With Artificial Intelligence Reduces Downtime, Helps Truckers Keep On Trucking

Millions of trucks transport fuel, produce, electronics and other essentials across highways every day. But unplanned downtime can exact a tremendous toll on any fleet operator and their customers who depend on timely deliveries. Volvo Trucks and Mack Trucks, subsidiaries of the Swedish Manufacturer AB Volvo, have met this challenge through remote diagnostic and preventative maintenance services based on IoT technologies with analytics and artificial intelligence from SAS. With these solutions, Volvo Trucks and Mack Trucks can help their customers maximize a vehicle's time on the road and minimize the costs of service disruptions by servicing connected vehicles more efficiently, accurately and proactively.

Volvo Trucks' Remote Diagnostics monitors data from each truck for fault codes triggered when something is amiss with a major system. Thousands of sensors on each truck collect streaming IoT data in real time to provide context around where the event happened and what conditions were present during the fault. Similarly, Mack Trucks' GuardDog Connect helps customers evaluate the severity of issues and manage repairs by remotely collecting data from the vehicle in the form of fault codes and other parameter data, then ranking them based on severity. If a fault requires immediate action, an agent contacts the customer to explain the situation and recommended action. If it's less time-sensitive or does not involve a potential injury, the repair is planned for when it makes the most sense for the operation.

The results of pairing sensor data and IoT technologies with SAS Analytics have been impressive. For Volvo Trucks, diagnostic time was reduced by 70 percent and repair time by 25 percent. Mack Trucks points to benefits for all stakeholders – dealers experience a more efficient process, and greater uptime keeps customers happy.

Four Keys to Success With AI and IoT

Looking beyond the physical infrastructure of the intelligent IoT – the sensors, cameras, network infrastructure and computers – there are practices that underpin a successful deployment:

- **Think real-time analytics**. Use event stream processing to analyze diverse data in motion and identify what's most relevant.
- **Deploy intelligence where the application needs it**, whether in the cloud, at the network edge or at the device itself.
- **Combine AI technologies**. AI capabilities such as object identification or processing natural language by themselves are valuable; used in synergy, they're indomitable.
- **Unify the complete analytics life cycle**, streaming the data, filtering it, scoring it, storing what's relevant, analyzing it and using the results to continuously improve the system.

When Is a Smart Device an AI Device?

Many smart devices are not AI-enabled devices. For instance, a device that can be controlled from an app or learn user preferences is smart, but that's not AI.

For a smart, connected thing to be a thing in the AI-driven IoT, it needs to be able to make a decision or perform a task without human intervention. For example:

- **A residential heating system** that learns temperature preference is not an AIoT system unless it does something – it adjusts the temperature on your behalf.
- **An autonomous vehicle** is an AI system – it drives for you. When it is connected to other cars or the internet, it is a "thing" in the artificially intelligent IoT – the AIoT.

Think Real-Time Analytics

Event stream processing plays a vital role in handling IoT data for the ability to:

- **Detect events of interest and trigger appropriate action**. Event stream processing pinpoints complex patterns in real time, such as an action on a person's mobile device or unusual activity detected during a banking transaction. Event stream processing offers quick detection of threats or opportunities.
- **Monitor aggregated information**. Event stream processing continuously monitors sensor data from equipment and devices, looking for trends, correlations or anomalies that could indicate a problem. Smart devices can take remedial action, such as notifying an operator, moving loads or shutting down a motor.
- **Cleanse and validate sensor data**. When sensor data is delayed, incomplete or inconsistent, a number of factors could be at play. Is dirty data caused by an impending sensor failure or a network error? A variety of techniques embedded into data streams can detect patterns and troubleshoot data issues.
- **Predict and optimize operations in real time**. Advanced algorithms can continuously score streaming data to make decisions in the moment. For example, information on a train's arrival could be analyzed in context to delay a train's departure from another station, so commuters won't miss their connections.

Analyze high-velocity big data while it's still in motion – before it is stored – so you can take immediate action on what's relevant and ignore what isn't. Seize opportunities and spot red flags hidden in torrents of fast-moving data flowing through the business.

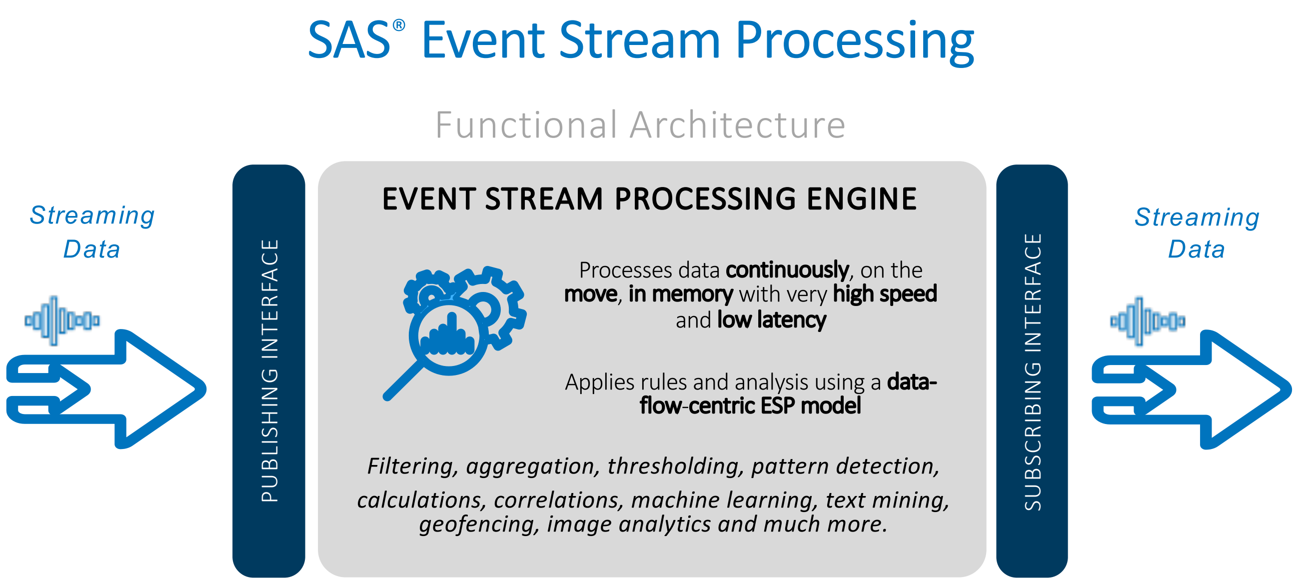

Figure 4: Event stream processing analyzes IoT data in motion to enable quick action based on what devices report at any moment in time.

Deploy Intelligence Where the Application Needs It

The use cases described earlier entail data that is constantly changing and in motion (such as a driver's geolocation or temperature inside a data center) as well as other discrete data (such as customer profiles and historical purchase data). This reality calls for analytics to be applied in very different ways for different purposes. For example:

- **High-performance analytics** does the heavy lifting on data at rest, in the cloud or otherwise in storage.
- **Streaming analytics** analyzes large amounts of diverse data in motion, where only a few items are likely to be of interest, the data has only fleeting value, or when speed is critical, such as sending alerts about an impending collision or component failure.
- **Edge computing** enables a system to act on the data immediately, at the source, without pausing to ingest, transport or store it – a must for many uses in the sensor-driven world of IoT devices and services.

It's a multi-phase analytical approach. The key principle to remember is not all data points are relevant and not all need to be sent to permanent storage. Sometimes the question calls for complex analytics, and sometimes speed is more important. Sometimes the data must be analyzed at the edge, and sometimes it needs to go back to a data center. The analytics infrastructure must be flexible and scalable to support all those needs today and into the future.

Combine AI Technologies

To realize the highest returns with AIoT, look beyond deploying a single AI technology. Take a platform approach where multiple AI capabilities work together, such as machine learning working with natural language processing and computer vision.

For example, a research clinic of a large hospital combines several forms of AI to provide diagnostic guidance to its physicians. The clinic uses deep learning and computer vision on radiographs, CT scans and MRIs to identify nodules and other areas of concern on the human brain and liver. This detection process uses deep learning techniques and convolutional neural networks, a class of machine learning commonly applied to analyzing visual imagery.

The clinic then uses a completely different AI technology – natural language processing – to build a patient profile based on family medical history, medications, prior illnesses and diet; it can even account for IoT data, such as pacemaker data. Combining natural language data with computer vision, the tool enables valuable medical staff to be much more efficient.

IoT Analytics Life Cycle

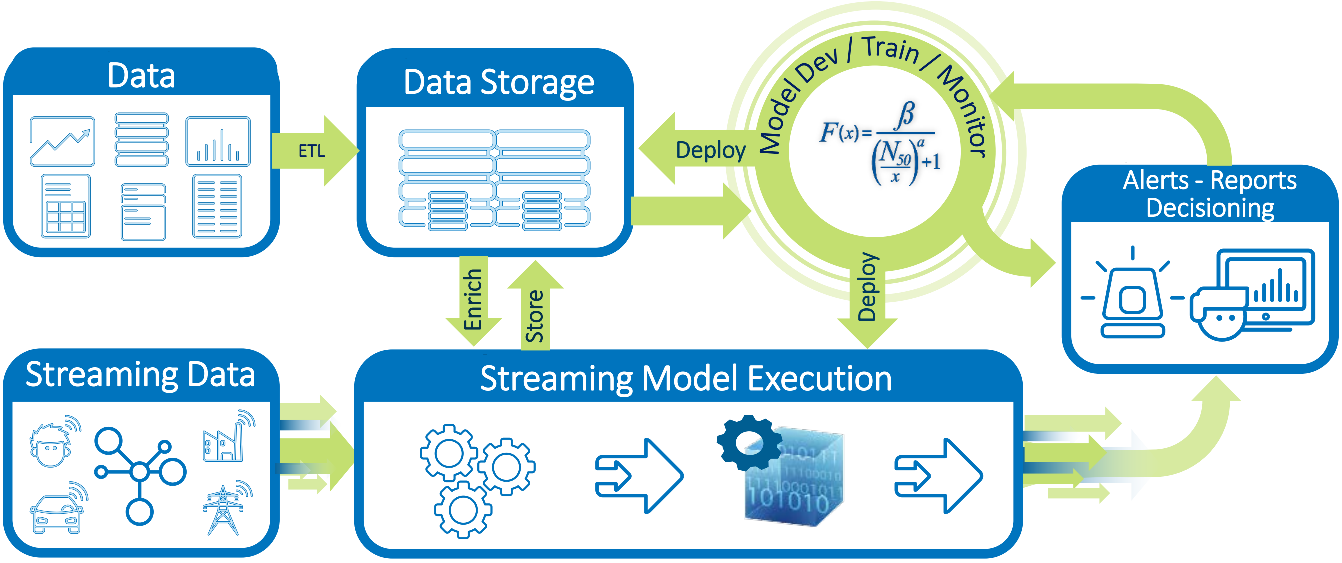

Figure 5: The IoT analytics life cycle – stream it, filter it, score it and store it.

Moving Intelligence to the Edge

Much of the value of the AI-empowered IoT is the promise to act now. Make customers the right offer before they look away. Detect the suspicious transaction before it is approved. Help that self-driving car maneuver through the busy intersection without crashing into other moving vehicles. Do it now. Latency matters.

Clearly, many types of sensors and devices cannot wait for data or commands from the cloud. And for other uses, it just isn't necessary. For monitoring, diagnosing and taking action on individual pieces of equipment, such as home automation systems, it makes sense to do the analysis as close to the device as possible. Sending locally sourced, locally consumed data to a faraway data center causes needless network traffic, delayed decisions and drain on battery-powered devices.

With the exponential increase in IoT devices and their data volumes, along with demand for low latency, we have seen a trend to move analytics from traditional data centers toward devices on the edge – the "things" – or to other compute resources close to edge and cloud – the fog.

A concept just a few years old, *fog computing* shifts data processing, real-time analytics, security and networking functions from a centralized cloud to distributed clouds closer to the IoT devices or services. Fog computing or "fogging" enables the data to be processed locally. Only the results, exceptions or alerts are sent to a centralized data center. Faster results, less bandwidth.

Unify the Complete Analytics Life Cycle

To achieve value from the connected world, the AIoT system first needs access to diverse data to sense what's important, as it's happening. Next, it must distill insights from the data in rich context. Finally, it must get rapid results, whether to alert an operator, make an offer or modify a device's operation.

Successful IoT implementations will link these supporting capabilities across the full analytics life cycle:

- **Data analysis on the fly**. This is the event stream processing piece described earlier. Event stream processing analyzes huge volumes of data at very high rates (in the range of millions per second) – with extremely low latency (in milliseconds) – to identify events of interest.
- **Real-time decision making/real-time interaction management**. The streaming data about an event of interest – such as a car's constantly changing location, direction, destination, environment and more – goes into a recommendation engine that triggers the right decision or action.
- **Big data analytics**. Getting intelligence from IoT devices starts with the ability to quickly ingest and process massive amounts of data – most likely in a distributed computing environment such as Hadoop. Being able to run more iterations and use all your data – not just a sample – improves model accuracy.
- **Data managemen**t. IoT data may be too little, too much, and certainly in multiple formats that have to be integrated and reconciled. Solid data management can take IoT data from anywhere and make it clean, trusted and ready for analytics.
- **Analytical model management**. Model management provides essential governance across the life cycle of analytical models, from registration to retirement. This ensures consistency in how models are managed – the means to track the evolution of models and ensure that performance does not degrade over time.

"We are on the cusp of another period of decentralization, moving analytics to the edge where data is generated in automobiles, industrial equipment, homes, wearables, retail stores and hospitals. In a sense, that is not unlike our efforts in in-database analytics – moving the analytics to the data – because moving data is too costly and clogs the network, and because increasingly data loses value if not acted upon at the right time."

– Oliver Schabenberger,
Executive Vice President,
Chief Operating Officer and
Chief Technology Officer,
SAS

How SAS Can Help

SAS has deep roots in machine learning and AI, with thousands of time-tested deployments. Machine learning is core to AI systems, and we are the pioneer in the field of using machine learning for enterprise analytics. SAS is embedding deep learning models and integrating cognitive capabilities throughout the SAS Platform to offer the latest advances in AI and analytics.

- **Comprehensive analytics**. SAS develops and continuously improves on the latest techniques to find those best suited for high-velocity, streaming data. Industry-leading data management capabilities can take IoT data generated anywhere and make it analytics-ready.
- **Proven event stream processing**. SAS Analytics for IoT is built on SAS Event Stream Processing, which analyzes complex and diverse data in motion by processing huge volumes at very high rates with extremely low latency.
- **A broad set of advanced AI technologie**s. The SAS Platform supports multiple AI capabilities such as machine learning, deep learning, computer vision, natural language processing, forecasting and optimization that can be used to solve a wide array of business problems.

- **Flexibility to run on a range of hardware or in the cloud**. SAS runs on a wide variety of platforms, including low-cost commodity hardware. It can run on big data appliances and in the cloud. SAS also works with many communication and hardware vendors to support embedded analytics in their edge devices, especially IoT gateways and high-performance IoT edge servers.
- **Support for the IoT analytics life cycle**. SAS covers the full analytics life cycle, from data discovery and exploration to management with embedded AI and machine learning models. Whether your data is at the edge, in motion or at rest, SAS helps you make swift decisions while reducing data movement and storage costs.

Successful IoT implementations will link the necessary supporting capabilities across the full analytics life cycle – from sensing what's important, to understanding it in deeper context, to acting on it, and closing the loop to learn from it for even better accuracy and speed at the next iteration.

If You Remember Only Three Things…

When You Think IoT, Think AI

The takeaway is clear: If you're deploying IoT, deploy AI with it. And if you're deploying AI, think about the gains you can make by combining it with IoT.

Either one has value alone, but they offer their greatest power when combined. IoT provides the massive amount of data that AI needs for learning. AI transforms that data into meaningful, real-time insights on which IoT devices can act.

AI and IoT already work together in our daily lives without us even noticing. Think Google Maps, Netflix, Siri and Alexa, for example. Organizations across industries are waking up to the potential. By 2022, more than 80 percent of enterprise IoT projects will have an AI component, up from less than10 percent today.[5]

"Without AI-powered analytics, IoT devices and the data they produce throughout the network would have limited value," says Maciej Kranz, Vice President of Corporate Strategic Innovation at Cisco. "Similarly, AI systems would struggle to be relevant in business settings without the IoT-generated data pouring in. However, the powerful combination of AI and IoT can transform industries and help them make more intelligent decisions from the explosive growth of data every day. IoT is like the body, and AI the brains, which together can create new value propositions, business models, revenue streams and services."

5 Gartner, Inc. Forecast: The Business Value of Artificial Intelligence, Worldwide, 2017-2025. By John-David Lovelock, Susan Tan, Jim Hare, Alys Woodward, Alan Priestley. March 12, 2018.

IoT Applications Already Benefit From the Power of AI

The technology is already proven for a huge variety of consumer, business and industrial applications. For example:

- Intelligent transport solutions are already speeding up traffic flows, reducing fuel consumption, prioritizing vehicle repair schedules and saving lives.
- Smart electric grids have already proven more efficient in connecting renewable resources, improving system reliability and billing customers on more granular usage increments.
- Machine-monitoring sensors already diagnose and predict impending maintenance issues, trigger deliveries where and when needed, and prioritize maintenance schedules.
- Data-driven systems are being built into the infrastructure of "smart cities," making it easier for municipalities to run waste management, law enforcement and other programs more efficiently.

Whatever the industry, there are use cases in place to learn from and build on.

A report from the McKinsey Global Institute estimates that the IoT could have an annual economic impact of $3.9 trillion to $11.1 trillion by 2025 across many different settings, including factories, cities, retail environments and the human body.[6] With AI, the realization of this impact is getting closer every day – and first movers take the prize.

SAS Is Leading in IoT With Embedded AI

Recognized as the analytics leader by industry analysts and influencers, SAS reinvests a high percentage of revenue annually to develop and continuously improve analytics techniques – 26 percent of our revenue in 2017 was reinvested in R&D. Our software is installed at more than 83,000 business, government and university sites, and 92 of the top 100 companies on the 2018 Fortune Global 500® are SAS customers. With industry-leading data management capabilities tuned for high-velocity, streaming data, SAS can take IoT data generated anywhere and make it analytics-ready.

We continue to innovate in contemporary AI areas such as:

- **Machine learning and deep learning** find insights hidden in IoT data without explicitly being told where to look or what to conclude, resulting in better, faster discoveries and action.
- **Natural language processing (NLP)** enables machines to intelligently interact with humans, such as via chatbots, and discover insights in large amounts of digitized spoken content.
- **Computer vision** analyzes and interprets what's in a picture or video through image processing, image recognition and object detection. This is the technology behind the WildTrack and SciSports successes.
- **Forecasting and optimization** help AI systems predict future outcomes based on IoT data and deliver the best results under given resource constraints.

6 What's New with the Internet of Things? By Mark Patel, Jason Shangkuan and Christopher Thomas. McKinsey & Company Semi-conductors.

AI and IoT Redefine the Possible

High-performance IoT devices and environments with thousands of connection points are proliferating across the network. It's the perfect storm. Declining hardware costs make it feasible to embed sensors and connectivity in just about anything. Advances in computing, light-speed communications and analytics make it possible to create AI-driven intelligence wherever it is needed, even at the fringes of the network.

Together, these technologies are ushering in a new era where the Internet of Things is just the state of things, and the term becomes superfluous, just as we no longer have to state "World Wide Web" or "internet-connected."

SAS has been at the forefront of this evolution for nearly 40 years. We can help you be there too.

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