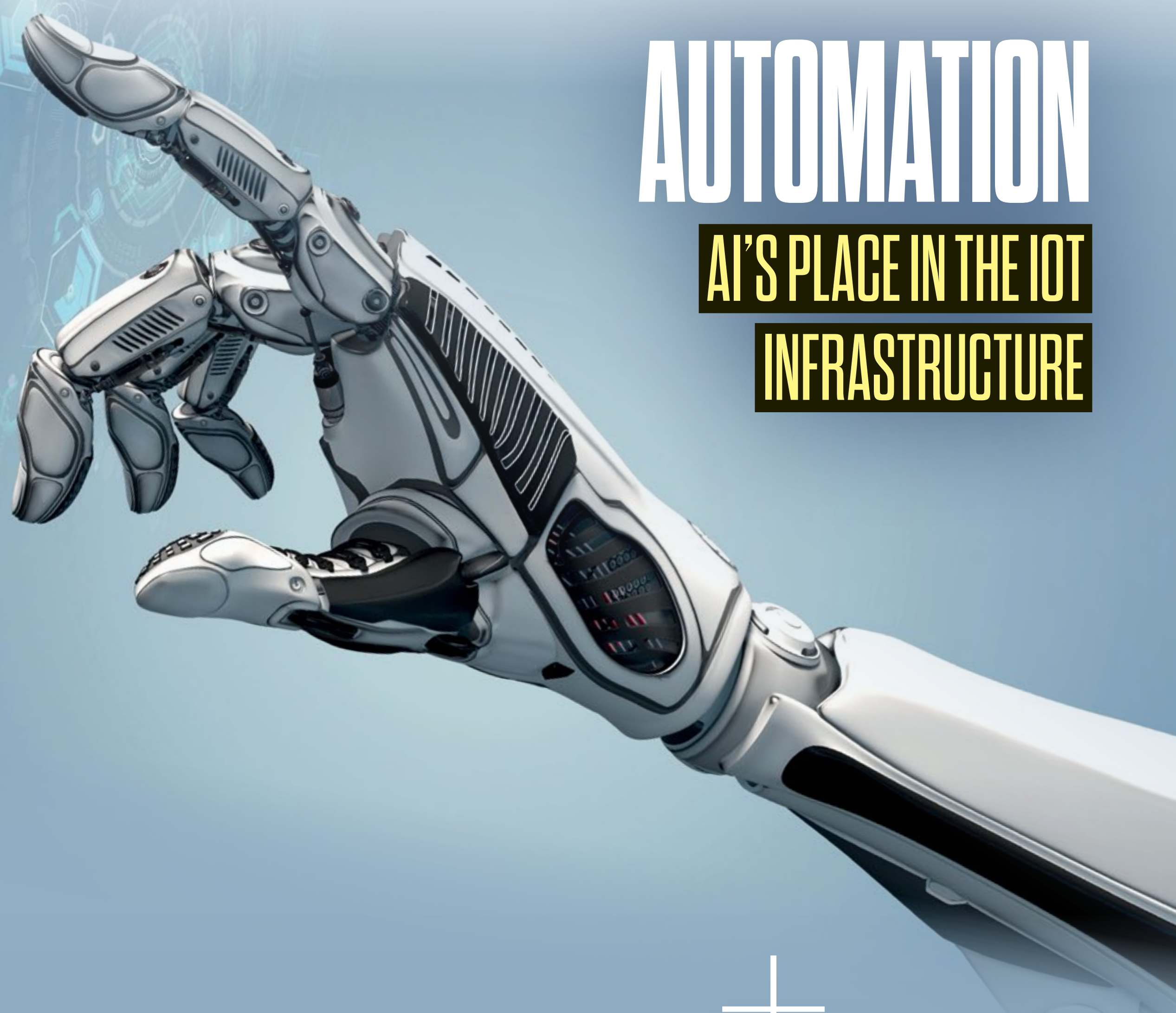
element14 TECH JOURNAL

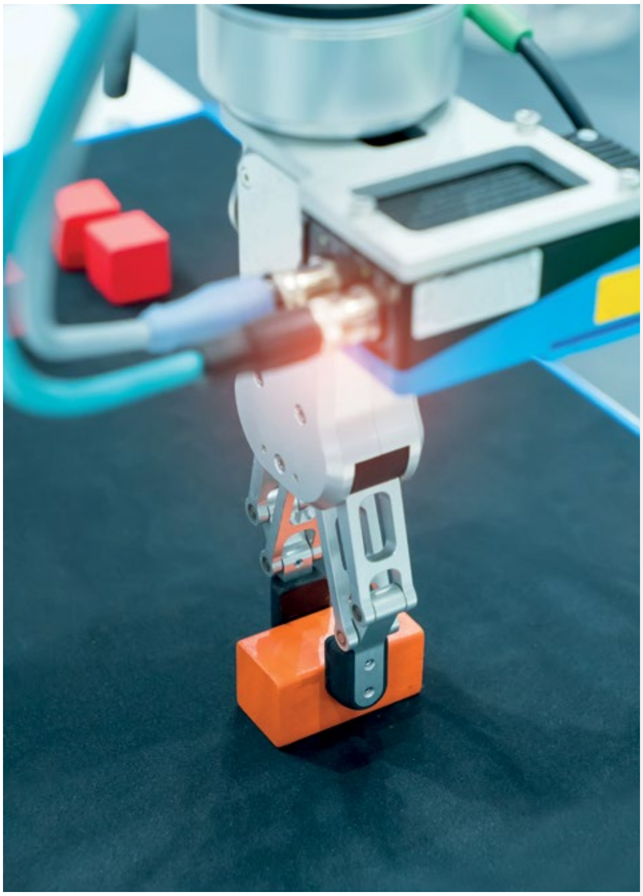


AUTOMATION

AI'S PLACE IN THE IOT INFRASTRUCTURE

CONNECTING DEVICES TO THE INTERNET OF THINGS

PLUS
- ARTIFICIAL INTELLIGENCE
- SUPPLY CHAIN MANAGEMENT
- FACTORY IOT SYSTEMS



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element14

Welcome

We are witnessing one of the greatest revolutions in all of human history – a revolution driven by Artificial Intelligence and the Internet of Things. Thanks to increasingly miniaturized computers, affordable sensors, ubiquitous networking, and the increasing availability of "smart" devices around the world. Increasing amounts of data from smart devices leads to better-informed decision making with algorithms being continuously improved either by analysts or automatically through machine learning. With all the possibilities for innovation, it's important businesses have the confidence to engage and incorporate these new technologies into their R&D strategy – to not do so may give their competition an advantage in terms of not only product differentiation but in productivity as well.

In this edition of *element14 Tech Journal*, we will help users understand Artificial Intelligence (AI) and how AI relates to the IoT and what benefits they bring together at all levels to the Industry 4.0. In addition, learn how Industry 4.0 can help to handle complexity with simplicity with smart machines and the key components of a smart factory. We also explore the role of Automated Guided Vehicles (AGVs) and Robotics in industrial automation and help provide answers for identifying the appropriate sensor solutions for the greater productivity and improved return on investment.

We will also take a peek into the challenges brick & mortar retailers are facing from the online world and how they are evolving with smart retailing fuelled by a wide variety of powerful technologies and ecosystems. And finally, learn more about the available wireless connectivity solutions and the best-suited network topologies for a different kind of Industrial Internet of Things applications.

We hope you enjoy this edition of *element14 Tech Journal* and welcome your comments and suggestions. Please feel free to drop us a note.

Cliff Ortmeyer Editor, Tech Journal
Email: editor-TJ@element14.com

SMART FACTORIES

HANDLING COMPLEXITY WITH FLEXIBILITY

The Internet of Things (IoT) is bringing revolutionary change to industry. Smart factories that use the IoT in Industrial IoT (IIoT) or Industry 4.0 implementations are already a reality, and on a large scale.

IN THE SIEMENS 108,000 square-foot Electronic Works facility in Amberg, Germany, smart machines coordinate the production and global distribution of the company's Simatic control devices – a custom, built-to-order process involving more than 1.6 billion components for over 50,000 annual product variations, for which Siemens sources about 10,000 materials from 250 suppliers to make the plant's 950 different products.

The endless variables and impossibly complex supply chain maze this production process requires far exceed the capabilities of a traditional factory. The IoT's rich arrays of sensors, robust networks and powerful computing capabilities become essential to success in such environments.

Other advanced manufacturers are also committed to Industry 4.0, not only in terms of their current implementation, but also through their investment into the technology's future.

"UNFORTUNATELY, IN THE WORLD OF SEMICONDUCTORS VOLUME IS EVERYTHING, AND SPECIALIZATION OF MICROCONTROLLERS INTO HYBRID POWER CONTROLLERS HAS PROVEN VERY CHALLENGING.

> **AUDI IS DEVELOPING MANUFACTURING FACILITIES** THAT ARE MOVING AWAY FROM THE TRADITIONAL ASSEMBLY LINE CONCEPT AND TOWARDS MODULAR ASSEMBLY.

Audi believes that the challenges to come require the vastly improved visibility, control and flexibility that only the IIoT can bring.

In Audi's view, perhaps the biggest of these challenges relates to flexible production of customised vehicles. Almost every car is ordered with some type of customisation, from body-colour mouldings to specially-sized light-alloy wheels, and demands are increasing. Additionally, new legislation is creating further demand for differing vehicle versions. As the number of variants and derivatives grows, accommodating their requirements within a rigid, sequential process becomes increasingly complex.

In response, Audi is developing manufacturing facilities that are moving away from the traditional assembly line concept and towards modular assembly. This involves small, separate workstations that allow highly flexible working routines, in terms of both time and space. Driverless transport systems move the car bodies and production parts between the workstations under the precise control of a central computer, which ensures a smooth workflow.

The workstations themselves employ a variety of robots to perform different tasks, from screw-assembling parts underneath cars to collaborative robots that pick up coolant expansion tanks and pass them to assembly workers – without any safety barrier, at the right time and in an ergonomically optimal position. In other applications, such as handling bumpers, industrial robot arms are used to save space while providing improved repeatability, shorter cycle times and continuous operation.

The success and development of this new, flexible production model depends partly on robust networking across and between all the factory's production and associated areas, together with advanced computing capabilities. However, the technology built into the robots and driverless transporters themselves is equally critical. Accordingly, let's look at the challenges created by these equipment types, and the technology available to meet them.

IN THE AUDI FACTORY, WIRE AND GUIDE TAPE SOLUTIONS ARE BEING REPLACED BY LASER SCANNERS THAT HELP WITH ORIENTATION AND SURROUNDINGS DETECTION, TO AVOID COLLISIONS. OTHER SCANNERS RECOGNISE OBJECTS HANGING FROM THE CEILING.

AGVS & ROBOTS

The driverless transport systems centre on automated guided vehicles, or AGVs. One type is controlled by a computer, while another moves autonomously along a defined route. Robots, the other key component in the smart factory example, divide into three main types.

01 INDUSTRIAL ROBOTS

THE LONGEST-ESTABLISHED are referred to as industrial robots. These are fixed-location devices used for tasks such as welding, painting, picking and placing, assembling, and loading objects onto pallets or into containers. Control signals come from a control cabinet next to the robot. Industrial robots are designed to perform tasks quickly, accurately and without direct interaction with humans. Accordingly, they are not designed to accommodate people within their working space, and have no sensors to detect human presence. Instead, they operate within walls, light curtains or arrays of floor mats and de-activate immediately if any of these safety barriers are transgressed.

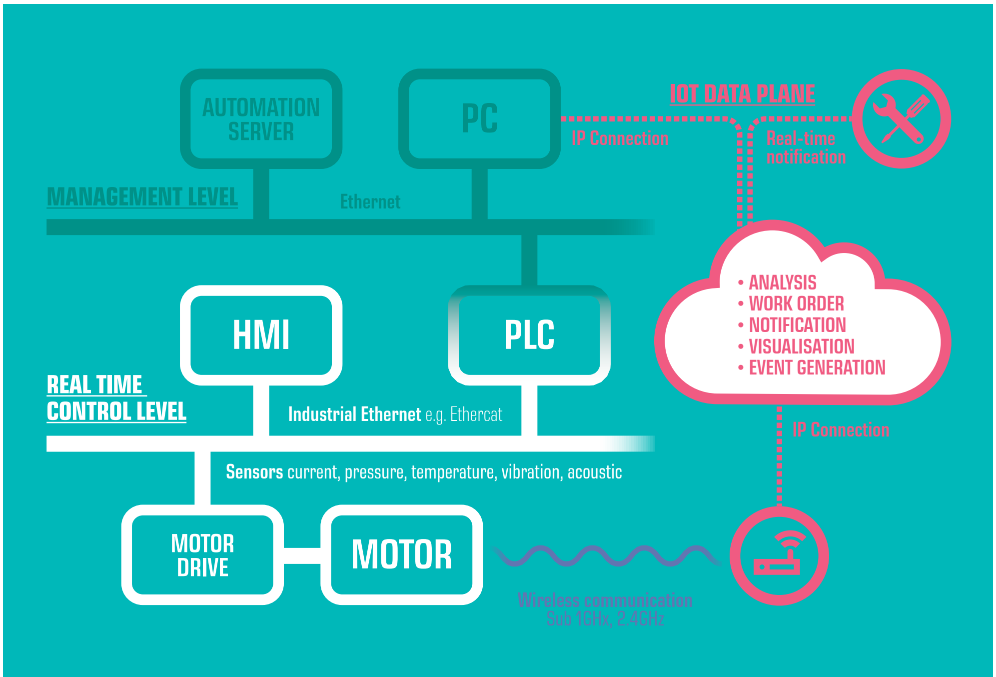
02 COLLABORATIVE ROBOTS

COLLABORATIVE ROBOTS are the second type, and have the most complex interactions with humans. A collaborative robot might hold an object while a worker inspects it, or perform fine-tuning tasks. The robot might then place the object where another robot can pick it up, possibly to move it in collaboration with a different worker.

This close interaction means that collaborative robots must maintain an elevated level of environmental sensing and redundancy to quickly detect and prevent possible collisions. If a sensor connected to a control unit detects a collision between a robot arm and a human or other object, the control unit de-activates the robot immediately. If any sensor or its associated electronics fails, the robot also turns off. Collaborative robots can either be fixed, or mounted onto a vehicle.

03 LOGISTIC ROBOTS

LOGISTIC ROBOTS ARE mobile units that typically operate in populated environments, for example fetching goods and bringing them to a packing station. These robots need a number of sensors for localisation, mapping, and collision prevention, especially with humans. Possible sensor technologies include ultrasonic, infrared and light detection and ranging (LIDAR).



PREDICTIVE MAINTENANCE IN FACTORY AUTOMATION

SENSING

Parameters that can be monitored for tell-tale changes include:

01 VOLTAGE
02 CURRENT
03 TEMPERATURE
04 VIBRATION
05 SOUND

ACTUATORS & PREDICTIVE MAINTENANCE

The driverless vehicles and robots have electric motors and other actuators that will fail without maintenance. By collecting information from sensors attached to the motors and analysing the data they provide, problems can be spotted and repairs effected before a failure and stoppage occurs.

ACCORDING TO TEXAS Instruments, a predictive maintenance system's sensor monitoring chain comprises remote sensing with data transmission and aggregation, factory-wide real-time communications, distributed control intelligence, and access to powerful computing and analysis resources. These components function together to monitor electromechanical systems such as motors, transport systems and robots, along with field transmitters and actuators, and give warnings of probable failures that can stop production.

In traditional preventative maintenance systems, a component's historic failure rate might be collected so that its likely time of failure can be predicted reasonably accurately. The component can then be replaced before its expected failure time – but with a good margin of error to minimise any possibility of a costly failure. This inevitably means that components are discarded with wasted working life, and maintenance intervals are shorter than they need to be; this could be improved on if only the right information were available.

Predictive maintenance is about supplying this information, collected from sensors mounted on motors or other actuators. This allows the electromechanical components to be run much closer to the true end of their working life, because the right sensor will reveal signs of their impending failure and allow a just in time response.

More data leads to better-informed decisions. Maintenance algorithms can continuously be improved, either by analysts or automatically through machine learning. Information can be fed back to parts manufacturers, leading to more robust, reliable components as well as immediate reductions in failure incidents and extensions to operational life.

■ PREDICTIVE MAINTENANCE

COMPONENTS

Adding predictive maintenance capability to a motor or robot calls for several components; an article by Texas Instruments has classified these as:

SENSORS

SENSORS THAT MEASURE temperature, vibration, noise, voltage and current must communicate with upstream nodes, often from locations that are hard to reach or environmentally challenging. Wire connections for power and communications become impractical, so the sensors must communicate wirelessly and drain minimal power from their battery or energy harvesting circuit.

To minimise the communications and power load, sensors may include fast, granular signal conversion capabilities, and be integrated with ultra-low power microcontrollers as well as communications. Set up and provisioning functions, sensor calibration, data aggregation and storage, data filtering and pre-processing can also contribute to this minimisation.

As well as being small, robust, low power and highly functional, advanced implementations may feature multiple sensor types within a single package, to enable installation into restricted spaces.

COMMUNICATIONS

AS PREDICTIVE MAINTENANCE sensors report on real-time conditions, they require fast communications with minimal latency, sometimes to defined industrial standards. Multiple protocols may be in use on the factory floor, so predictive maintenance communications should be compatible with the most widely used standards. Predictive maintenance capabilities may not need to interface at all levels within an existing factory network; they can be added as a parallel or secondary network, with links at certain key points.

GATEWAYS

MCUS CONNECTED TO sensors typically forward the sensor data to gateways, either directly or through aggregation nodes. The gateways in turn transmit information to cloud-based resources that process, analyse and store the incoming data, and make predictive maintenance decisions. However, communications to the cloud can always be lost, so the gateway should be capable of local calculation and decision-making; issuing warnings or even initiating a system shutdown.

Gateways are also useful in large systems with high numbers of sensors. The volume of data sent to the cloud can be reduced if the gateways pre-process the data they receive before transmitting it on to the cloud. In some applications, the gateways can also perform automation and control functions.

SECURITY

PREDICTIVE MAINTENANCE systems must be as secure as any other factory network. Sensors, data aggregation nodes, gateways and cloud-based systems must be completely secure from hacking at both software and hardware levels.

RELIABILITY

INDUSTRIAL SENSORS are subject to harsh environments that may include extremes of cold and heat, vibration, dirt, grease, vapor, chemicals and a variety of other potentially damaging conditions. Sensors and other maintenance integrated circuits must be characterized for use under extreme conditions to ensure continued reliability on the factory floor.

SAFETY

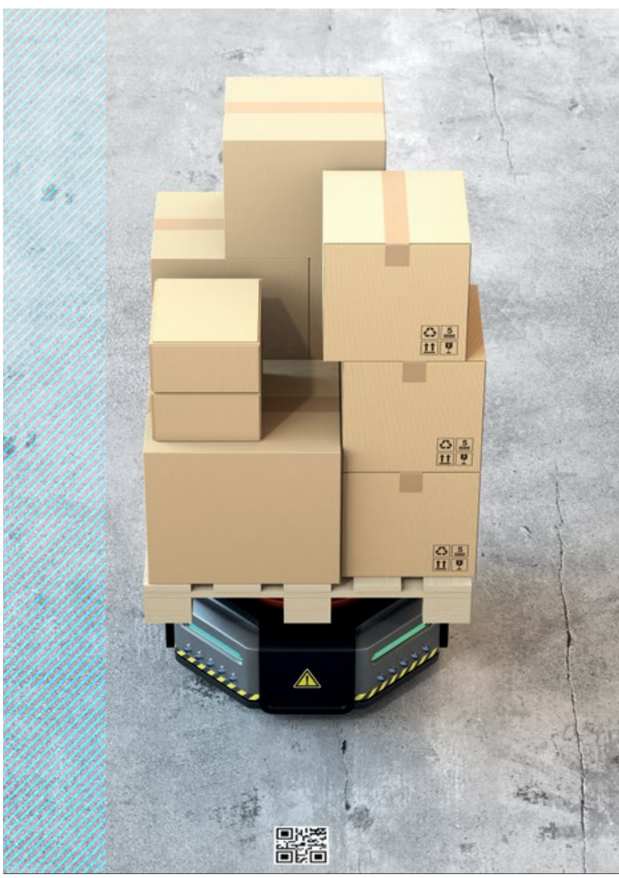
STATISTICALLY, EVEN the most reliable sensors and integrated circuits will suffer some failures over time. Design at system level must allow for this and prevent such failures causing harm to the factory and its operators.

THE ROLE OF SENSORS

PRECISE FAST OPERATION WITH SAFETY

DRIVERLESS VEHICLES

Each activity within an AGV's operation cycle creates its own challenges and a corresponding demand for appropriate sensor solutions.



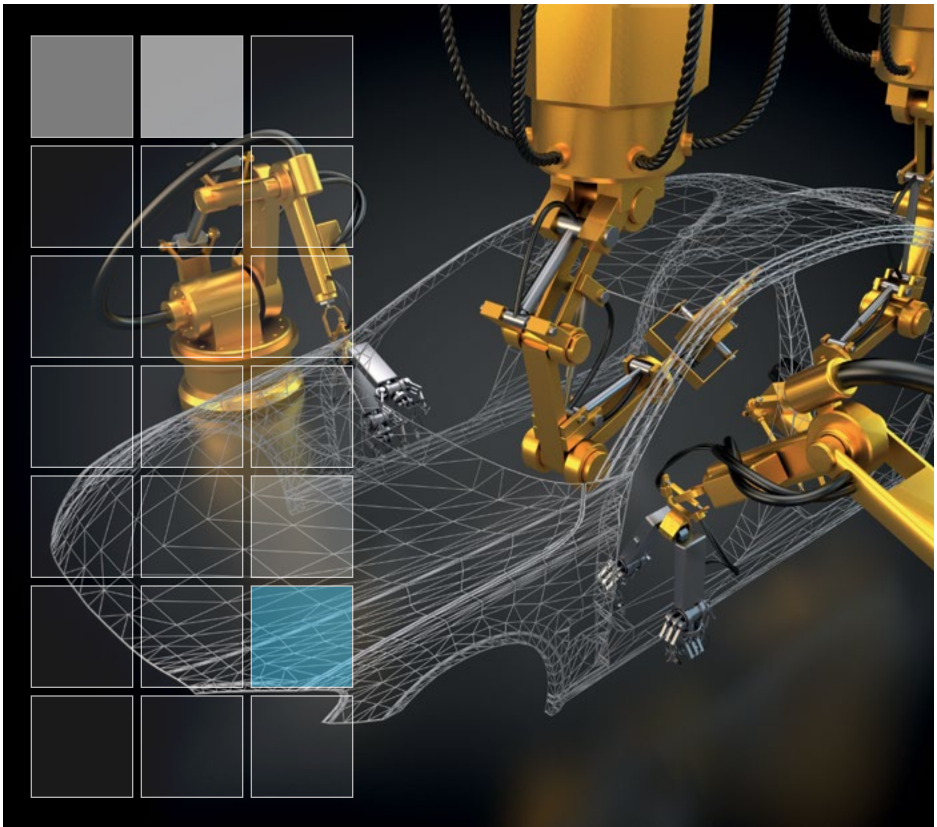
PROTECTION OF HUMANS is paramount as these fast-moving and sometimes heavily laden vehicles traverse the factory floor, but goods in automated areas must also be protected. The AGVs must identify goods and storage spaces, and detect free storage space. Robust communication with controlling and regulating networks is also essential.

Laser measurement systems can provide quick and accurate navigation using either space contour data, detection of reflector marks, or a combination of both. Safety functionality and collision prevention can also be added to the laser navigation system. Data from incremental encoders on the vehicle's drive and steering axles can be used to control and limit vehicle speed.

In the loading area, photoelectric sensors can be used to control the feed conveyor, check whether the loading area is free and whether the AGV can approach without damage, and then check whether the goods have been placed onto the AGV without obstruction.

Goods on board the vehicle can carry RFID tags, containing information about the items and their packaging and pallets. RFID identification stations can collect all this data from AGVs that pass through them for storage and transfer to a central computer.

On board controllers can collect data from all of these sensors, for transmission over an industrial wireless LAN to a central computer. Integration can be eased with support for widely-accepted communications protocols such as PROFIBUS, PROFIsafe, DeviceNet, DeviceNet Safety, AS-i, AS-i Safety at Work, CANopen and Ethernet.



ROBOTS

We have defined the three types of robots – industrial, collaborative and logistic – found in today's smart factories.

TO FULFIL THEIR PROMISE OF greater productivity and improved return on investment, all robots must perform difficult tasks with precision and complete repetitious tasks rapidly. Additionally, safety must always be part of the equation; a particularly demanding requirement for collaborative robots, which work in close partnership with, and proximity to, human workers.

Robots can also save investment on more specialised machines, and complete short production runs efficiently – sometimes for previously non-viable applications. Advanced communication capabilities, allowing data exchange between robots and with higher-level control networks, are also essential if robots are to fulfil their contribution to a fully integrated factory; an environment where more data, freely exchanged, allows better process control and maintenance, while enabling a production resource that's more responsive to changing product demands.

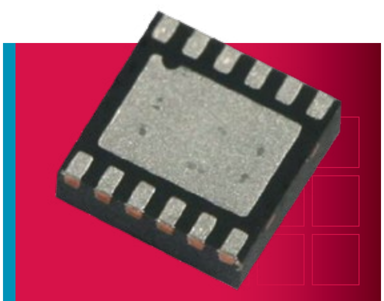
Evolving robot design which meets these productivity, safety and communications objectives depends ultimately on advanced integrated circuit solutions. Overall, these solutions must provide precise sensing, high speed sensor signal conversion, fast computation and signal processing for real-time response and high-speed communications. Integrated circuit technology also facilitates the high-efficiency, small form factor power supplies needed by the sensors and computational devices.

Texas Instruments has defined the required features of integrated circuits used in robot applications as below:

- A high-efficiency, high-voltage power supply with circuit protection and low-noise emissions
- Characterization for an extended temperature range
- Support for industrial ethernet and other widely used industrial communication standards
- Ease of programming for greater flexibility
- Fast, precise analogue-to-digital and digital-to-analogue signal conversion
- Reinforced isolation to meet industrial safety standards
- Control redundancy for safety-critical applications when combined with other integrated circuits
- A small footprint when placing circuitry in tight spaces such as mobile logistic robots, or for motor control in robot arms (not to mention other equipment with tight spaces, such as sensors and motor housings)
- Low power consumption (critical for battery- or ambient-powered equipment such as logistics robots and sensors)
- Comprehensive support, including reference designs and evaluation modules (EVMs) to minimize design time and let designers focus on value-added technology.

INTEGRATED CIRCUITS THAT FULFIL THESE REQUIREMENTS

TI offers integrated circuits and support services within all these areas. Products cover sensor inputs and actuator and motor outputs, and communications across the entire signal chain, from equipment and workstations, to factory floor or higher levels.



TI INDUCTIVE SENSOR

Texas Instruments

LDC1312DNTT Inductive Sensor

PART# 2465054

The LDC1312DNTT is a 2-channel 12-bit Inductance to Digital Converter (LDC) for inductive sensing solutions with multiple channels and support for remote sensing.

FEATURES INCLUDE REINFORCED ISOLATION, AND PRODUCTS ARE TESTED AND QUALIFIED FOR USE IN HARSH INDUSTRIAL ENVIRONMENTS. THIS COVERAGE CAN BE REPRESENTED BY THE FOLLOWING KEY PRODUCTS AND AREAS:

01 SITARA PROCESSORS

These processors are designed for flexible, fast design in robots and other industrial equipment. Based on ARM Cortex-A cores, they provide flexible peripherals, connectivity and unified software support. A broad portfolio of single- and multicore devices offers a balance of integration, connectivity and performance. A fully scalable software platform enables a unified software experience for simplified development and code migration across Sitara processors and TI digital signal processor (DSP) families. Pin-compatible options within processor families make hardware upgrades seamless.

02 PROXIMITY SENSING

TI's sensing technology can be used to provide collaborative robots with the sophisticated sensing of nearby objects and people essential to make them safe. TI sensors are available to measure target objects' distance as well as their presence. Sensor technologies include ultrasonic, magnetic, capacitive, inductive and Time-of-Flight (ToF). TI's 3-D ToF chipsets allow for maximum flexibility to customize designs for robot vision and other applications.

03 GAN POWER

In addition to an extensive power management portfolio of switching and linear regulators, switching controllers, power monitoring and other supporting power management devices, TI offers GaN modules, drivers and controllers that provide outstanding power density for high-voltage power supplies in industrial systems. GaN technology greatly reduces switching losses and therefore enables faster switching speeds while minimising or eliminating heat sinks.

04 INDUSTRIAL NETWORKS

A network designed for use in industrial applications requires determinism and real-time control. Examples of Ethernet protocols that provide these features include EtherCAT, PROFINET, EtherNet/IP, PROFIBUS, Ethernet Powerlink, Sercos and others; the PRU-ICSS subsystem within the Sitara microprocessor supports these protocols.

IIOT DEVELOPMENT ACTIVITIES

Manufacturers offer support tools including dev kits to help designers move rapidly into the product differentiation, value-adding stage of their project development. Here are some examples.

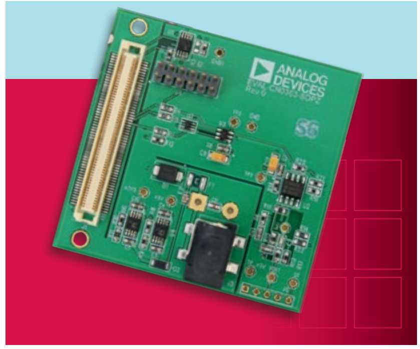
CONCLUSION

The concepts of the Smart Factory, IIoT and Industry 4.0 have futuristic overtones, but many organisations are implementing them now as well as investing significantly for the future.

Productivity, flexibility and safety are the goals, while AGVs and robots of various types are making major contributions to achieving them.

These machines must function as nodes on the factory network, while performing their tasks with speed, accuracy, flexibility, safety and reliability. This article has shown how designers have opportunities to continue improving these aspects of AGV and robot performance, through the availability of advanced integrated circuits and support products. Faster, better solutions can be developed for sensing, signal processing, local processing, power management and communications. Innovative predictive maintenance designs can extend component life, improve designs for reliability, and alert operators of impending component or equipment failure before it leads to a production stoppage.

Discussing your ideas with Farnell at the outset of your project won't cost you anything, but could save you considerable time and money. As a Development Distributor, Farnell has the expertise to advise you on developing and building your prototype faster, backed by products, test equipment and custom development services. This support continues into production, with deliveries from tape and reel services for components to spares and consumables for maintenance.



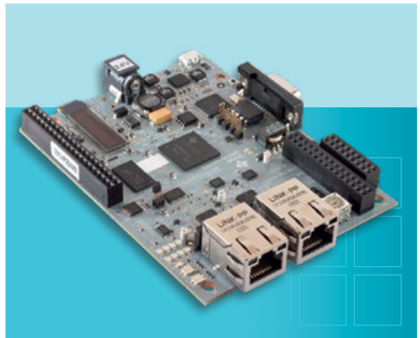
ANALOG DEVICES VIBRATION SENSING EVALUATION BOARD

Analog Devices

EVAL-CN0303-SDPZ

PART# 2361285

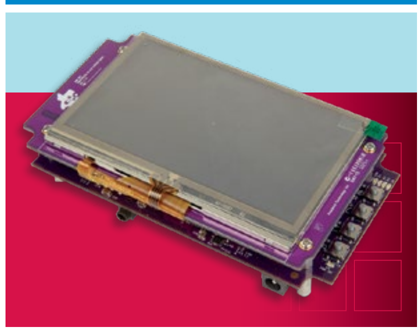
Analog Devices' EVAL-CN0303-SDPZ Evaluation Board for MEMS based Vibration Analyzer with Frequency Response Compensation. The circuit provides a low power solution suitable for bearing analysis, engine monitoring and shock detection. This provides a 3-D location of each pixel for accurate depth maps that aid customization for a given application.



Texas Instruments

TIDEP0061

The TIDEP0061 reference design implements an applications example of a 4-axis CNC router based on the Simple Open Real-Time Ethernet (SORTE) protocol and Sitara PRU-ICSS unit.



TI SITARA STARTER KIT

Texas Instruments

TIDA-00913

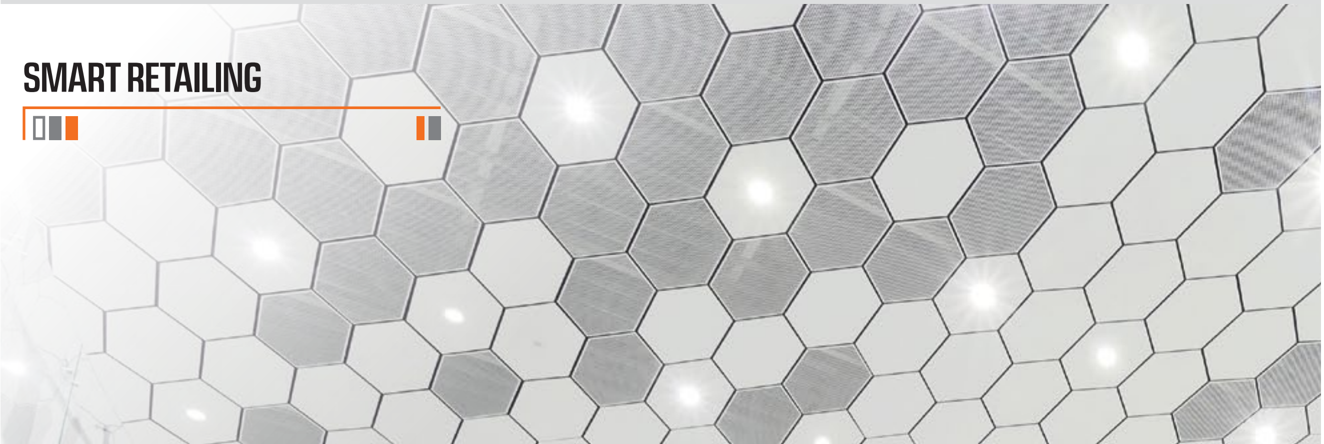
The TIDA-00913 is a reference design that uses a GaN inverter for accurate control of precision drives such as servo drives.

Texas Instruments

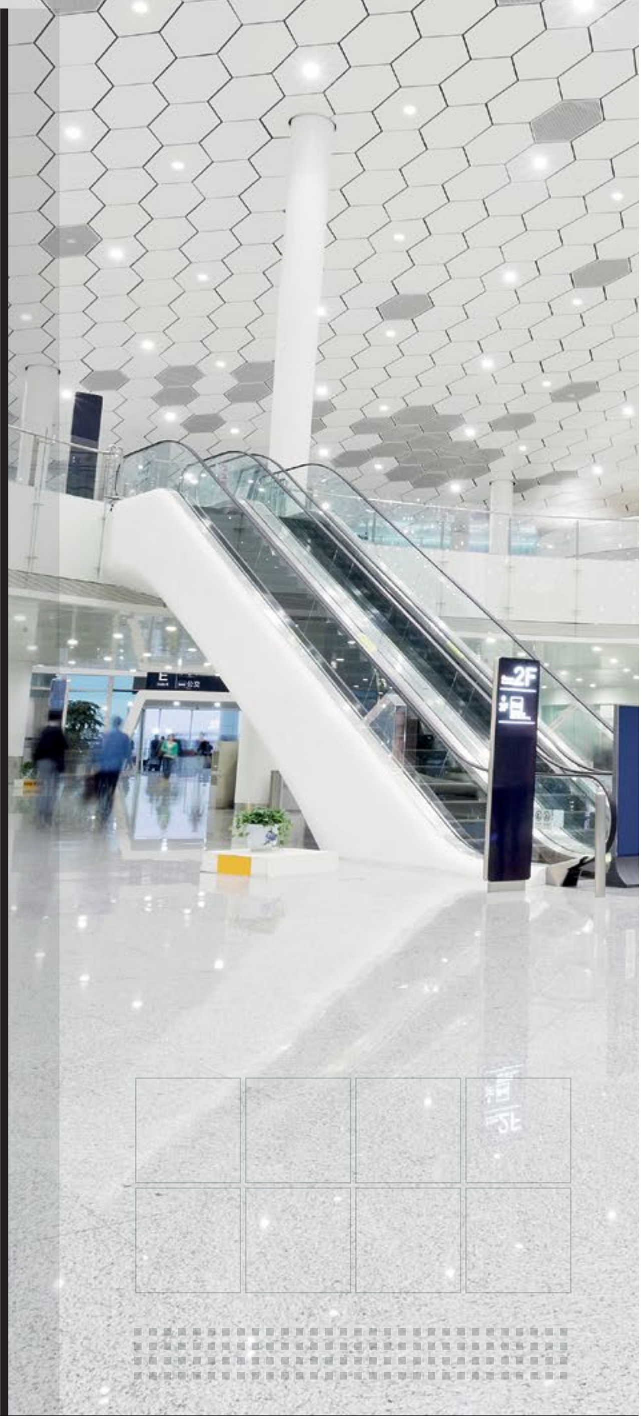
AM335x Starter Kit

PART# 2164379

TI's AM335x Starter Kit (EVM-SK) provides a stable and affordable platform to quickly start evaluation of their Sitara™ Processors. TI also offers an EVM and a highly configurable camera development kit (CDK).



THE BRICK AND MORTAR RESPONSE TO TODAY'S ONLINE CHALLENGES



Smart retailing has become firmly established as a reality rather than a concept. It reflects how retailers are working to deal with the disruptive forces the $15 trillion sector now faces; an upheaval that a joint Intel Labs/The Store WPP report refers to as 'The second era of digital retail'.

HERE, WE LOOK AT these present challenges for retailers, and how they can use IoT technology – smart devices, dense arrays of sensors, massive yet affordable computing resources and sophisticated analytical capabilities – as part of their response. We take a closer look at the technologies underlying grocery operations like Amazon Go, then contrast these with the strategies now appearing in two other important retail sectors – clothing and furnishing.

intel.com/content/dam/www/public/us/en/documents/reports/futurecasting-report-june-4.pdf

A PERFECT STORM IN RETAIL

The 'Second Era' report describes how retail is facing a perfect storm of change fuelled by a wide set of powerful technological, social, demographic, ecosystem, business, and economic forces.

CUSTOMERS NOW have a new set of expectations related to omni-channel (seamless virtual plus bricks-and-mortar) shopping, customisation and personal experience, efficiency, transparency, and the quality of the experience itself. They also enjoy increased choice as retailers battle for their custom in increasingly competitive environments.

Manufacturers equally expect more from their retail outlets; increased visibility and new services including shopper analytics, targeted advertising, and other analytics and insights. Additionally, the shift towards online sales has changed the retail landscape forever and requires totally new thinking; this change will continue to disrupt retail as increased delivery speeds undermine immediacy as a channel advantage for traditional retail.

Against this background there is also the combined challenge and opportunity created by Moore's Law, which is delivering ever-more computer capability as costs, sizes and energy barriers diminish sufficiently to disrupt retail strategy. The implication is that ultimately any object can be made both smart and connected as these barriers disappear. These properties translate into commercial advantages if the data made available from the growing hordes of smart devices can be successfully captured by powerful computers and converted to information that provides actionable insights.

According to the Intel report, while the first era of retail digitisation was about supply chain management, inventory and payment systems, the second era will be shaped by sensors, data analytics, robotics, natural interfaces, and computing ubiquity. The drive is to improve the shopping experience by making it more personal, efficient and fun for consumers, while continuously improving retail efficiency, enabling new business models, maximising revenue, and speeding fulfilment and delivery.

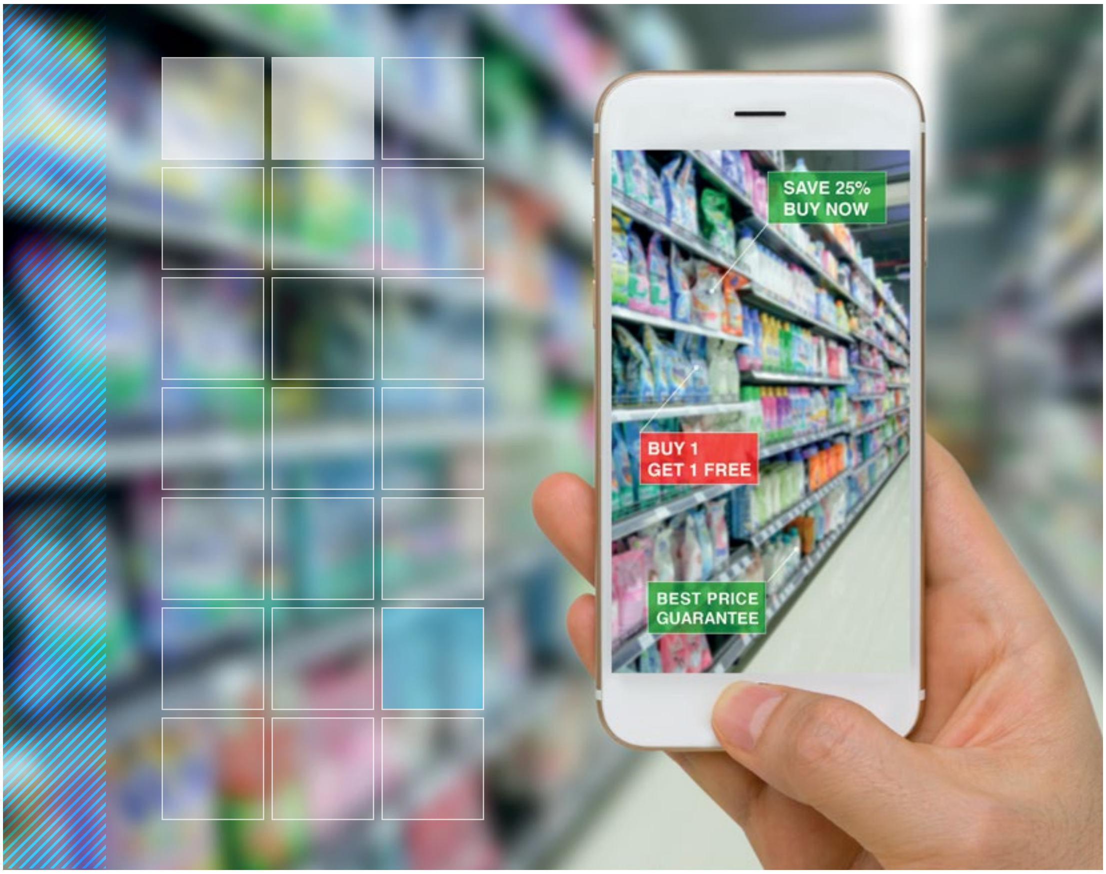
INSIDE THE SMART STORE

If smartness is about gathering data and communication with customers and suppliers, then the store's shelving and its potential for intelligence plays a core role.

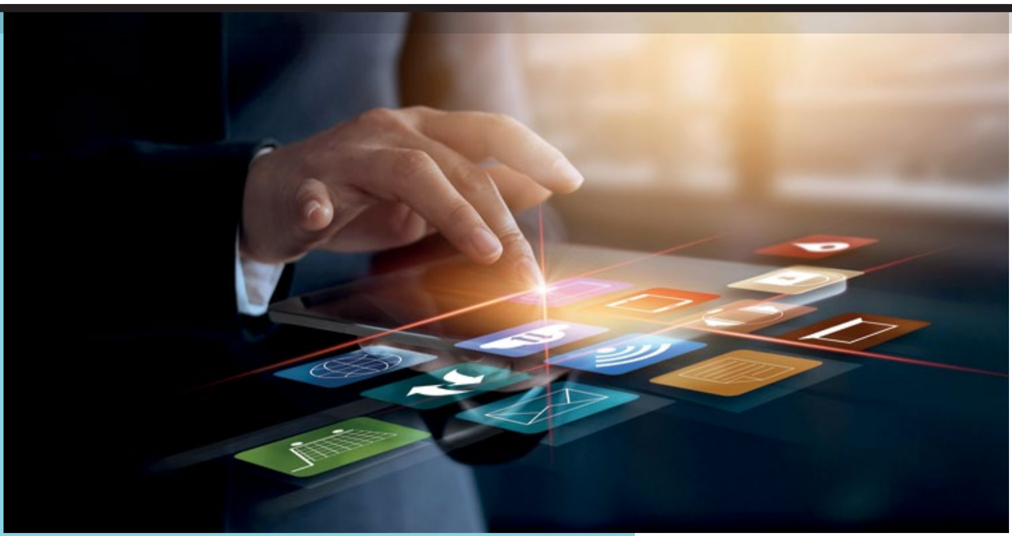
MAKE A SHELF smart, and it will revolutionize the level of service retailers are able to offer to manufacturers and shoppers alike. It will interact with the shopper in a way that is natural, comfortable, and fully respectful of shopper privacy. Shelves will understand natural human language, context, and even sense emotional states. They will serve shoppers intelligently by assessing whether they are stressed, relaxed, in a hurry, confused, in discovery, or close to making a purchase decision.

Like any good sales person, the shelf will have a personality that combines deep product knowledge, trustworthiness, great shopper insight and strong selling skills. It will navigate a wide range of conversations, make choosing easier for the shopper and move them towards purchase. Smart shelves will also handle loss prevention, and manage samples, inventory and assets.

To unlock maximum value, smart shelves will need to be supported by a sophisticated back-end server infrastructure able to gather, store, and analyse data, and deliver media and other services to the shelf.



SHELVES CAN SERVE PARTICULAR PROMOTIONS AS SHOPPERS ARE CLOSE TO MAKING A PURCHASE DECISION.



EASY TO USE INTERFACES COULD BE HIGHLY CUSTOMISED AND ATTRACTIVE TO SHOPPERS.

According to the Intel report, shelving could rationalise into three types; 'Good', 'Better' and 'Best'.

GOOD SHELVES

Good shelves will have basic sensing and limited display capabilities, and no communications.

BETTER SHELVES

Better shelves will have more sophisticated sensors, more local intelligence, and better cloud interaction.

Proximity sensors will be replaced by capabilities to see, smell, feel, understand and intuit the world around them. They will detect the contents they hold using cameras, RFID readers, weight sensors or other technologies. At the same time, they will interact with the shopper in front of them using 3D cameras, microphones, proximity and touch detectors, together with local computing resources that will obviate the need for cloud processing with its privacy concerns.

A practical example of a sensor-rich smart shelf design appears below, under 'Highly-integrated smart shelves'.

BEST SHELVES

The best shelves will add further cloud-based resources to these capabilities, to deliver product information, social media reviews, discounts, and personalized shopping guidance for each shopper.

Dynamic or personalised pricing, and promotional offers, will also be possible. Some shelves may use the shopper's smartphone – the display, touch screen, microphone and even processor – as a part of the interaction. Others will rely on their own hardware. This could include displays, from OLED or LED to high quality video or ultimately holographic devices. However, display deployment will have to be carefully considered, as too many bright screens in a limited area may become overwhelming.

Conversely, easy-to-use, fun interfaces – possibly including touch, gesture, augmented or virtual reality – could make two-way conversations and exercises in customisation highly attractive to shoppers.

Smart shelves with sufficient computing power will also be able to engage in natural conversations, responding, for example, to a shopper's question about where to find a product.

THE SHELF COULD then make further suggestions of possible interest to the customer, based on its knowledge of the customer's purchasing history. Manufacturers will benefit from insights into traffic, linger times, customer demographics, and success of offers or advertising. Shelf sensors, and cameras using machine vision, could constantly report on inventory levels, and arrange for replenishments to be sent when products are running low. The sensors could also spot shoplifting attempts. Customer behaviour gathered by shelf sensors and store movement trackers, and sent back to a cloud analytics resource, will need to be integrated with data gathered relating to online behaviour – clicks, hovers, shopping carts and wish lists.

An innovative technology called NeWave Smart Shelf allows retailers to continuously monitor shelf stock levels without needing RFID tags on individual items. The tags are located instead on the shelf's product pusher, and become visible when the item is removed. The system can also raise an alarm if too many items are removed simultaneously, signalling a theft in progress. This can be backed up by video capture of the activity.

Perishable foods can be protected by passive UHF temperature-sensing RFID inlays available as low-cost alternatives to active RFID tags or data loggers. These SMARTRAC devices' on-chip temperature-sensing circuit can digitise a product's temperature reading into a 12-bit number which can be read by a UHF reader, along with the tag's unique identifier. Basic moisture-sensing capabilities are also provided, based on measurement of impedance changes.

newaverfid.com

RETAIL

HIGHLY-INTEGRATED SMART SHELVES

We have highlighted different benefits that can be gained from smart shelf technologies. Yet many retail operators will be interested in sourcing integrated solutions comprising components that co-operate to provide a better shopper experience while gathering and analysing retail data for management and improvement.

HERSHEY USES INTEL-BASED AWM SMART SHELVES TO KEEP RETAILERS IN THE LOOP ON SHRINKING INVENTORY AND SHOPPER STATISTICS.

PACKAGED IN-store analytics solutions are available from companies like Hybris Labs. Their 'Funky Retail' solution can identify customer presence, count the product lift-ups, measure the lift-up time, and relate individual product lift-ups to a promotional product video.

However, smart shelf solutions that make more intensive use of multiple-type sensor arrays as envisioned by Intel are in the pipeline; these will offer more detailed, real-time information to both shoppers and the retailer. One example is a United States Patent Application, titled 'Smart shelves for retail industry' filed by inventors from IBM in February 2016 and published in August 2017.

Each shelf in this system has a mesh arrangement of sensors that includes strain sensors, photo-detectors, microphones and spillage detectors, together with a data processing system for handling the sensor signals. The sensor mesh layer is fitted into the bottom of each shelf. The system also includes a set of video displays for showing characteristics of the products being sold from the shelf; these characteristics are delivered by a set of wireless transmitters.

The storage devices can be of any type. The user input devices can be any mix of keyboard, mouse, keypad, and/or devices for image capture, motion sensing, smell detection, light detection, microphone, or fused devices containing more than one of these functions. Other devices can also be used. Multiple shelves containing different products can be integrated into one system; each shelf's data processing unit can interface with a central store server which controls various store systems such as personal scheduling, personal information, lighting, security item monitoring and stock control.

The central server can then provide access information such as pager, SMS or email addresses for employees so that they can be contacted and updated about low stock or other situations.

The video displays can show product characteristics such as price, weight, chemical freshness determined by colour or methane emission, nutritional values, calories, recipes, expiration dates and other information as required. They can also show promotions of related products of possible interest.

A 'RESTOCK ALERT' SIGNAL CAN BE GENERATED IF THE WEIGHT DROPS BELOW A PRESET CRITICAL VALUE.

Strain sensors within the mesh can provide a voltage signal proportional to the weight, and therefore the number of products placed on to the shelf. A 'restock alert' signal can be generated if the weight drops below a preset critical value. Photo-detectors can have filters to indicate that a certain item with a specific colour is on the shelf. If the item shows a slow change in colour – for example a banana turning from yellow to brownish, or milk coagulating in a bottle and changing colour – the photodetector's changing voltage will alert the retailer accordingly.

Microphones can monitor for sounds that indicate when a container expands due to its contents being compromised or handled improperly on the shelves. These microphones can be implemented using strips of piezoelectric material that generate a signal on detection of small vibrations. Overall, the various sensors can be integrated into one sheet comprising one layer for a strain detector, the next for a photo detector, another for an acoustic sensor, and others as required.

The strain sensors can include a patterned foil laminated to the bottom of the smart shelf. Circuits can be printed onto the foil using silicon, germanium and other materials that make it sensitive to different phenomena. For example, chemical sensing can be achieved by printing tin oxide on top of a transistor, because the current flowing through the circuit will increase as methane levels rise. Similarly, a light detector can be created at the junction of two dissimilar materials such as silicon and germanium. This can detect light in a spectral band associated with merchandise packaging colour.

The sensor layers can be perpendicular strips forming a cross bar structure with arbitrary orientation. Multiple discrete elements can be included to allow items to be placed haphazardly on the shelf, if this arrangement is more desirable than a regular 'row and column' arrangement.

Data can be sent from the radio transmitters using Bluetooth, spread spectrum radio, mesh radio, ZigBee, Global Systems for Mobile Communications (GSM), Code Division Multiple Access (CDMA), General Packet Radio Service (GPRS), Wideband Code Division Multiple Access (WCDMA), Enhanced Data Rates for GSM Evolution (EDGE) (also known as Enhanced GPRS or EGPRS), CDMA 2000 or other wired, wireless or hybrid standards.

This is a possible solution from one vendor, but retailers may find themselves using multiple vendors across their operation. Accordingly, standards for data analytics must emerge; the industry will need to define standard interfaces and a set of open APIs that enable developers to collaborate with each other across standardised platforms. For example, content delivery will benefit from standard screen sizes, formats and resolutions for on-shelf advertising.

CUSTOMER LOCATION DETECTION

While smart shelves, and the processing power they may be fronting, are key to the emerging 'second era of retailing', they are complemented by another important data source; location-based services, with sufficient precision to be applied within the confines of a store. Such data can be analysed to understand shopper footstreams to gain increased insight into shopper behaviour, store layout and user experience.

Location tracking is either passive, when the customer is merely carrying their smart device but not using it, or active, when they are using it to obtain information or service based on their location.

Different techniques, of various levels of accuracy, refinement and development state, can be summarised as below:

01 WI-FI TRIANGULATION

Already in deployment, but of low accuracy – about 30m.

02 WI-FI FINGERPRINT

A more sophisticated version of Wi-Fi triangulation that uses learning algorithms to map a store's wi-fi profile. Early trials indicate a precision of 2-5m.

03 BLUETOOTH LE BASED BEACONS

Beacons such as Apple's iBeacon technology can trigger offers to a shopper's device when they are within range of an iBeacon transmitter. The range of the transmitter can be adjusted to cover a small area (5m radius) or the entire store.

04 ACCELEROMETER & INERTIA

A smartphone's accelerometer can be used with limited accuracy and success; currently it is only viable when used to augment other location techniques.

05 SEMANTIC LOCATION

This uses signal processing on Wi-Fi signals over time to help refine location when it is unclear which side of a wall a shopper is located.

06 AMBIENT AUDIO

Different stores have different ambient noise signatures. This can be exploited to help with other, inconclusive location information to make a final determination of position.

07 ACTIVE AUDIO

Some stores are experimenting with adding audio signatures to their in-store piped music to help devices understand where they are.

08 OTHER APPROACHES

Other approaches include visual triangulation, visual fingerprint (similar to Wi-Fi fingerprint), and magnetic field, which uses a smartphone's digital compass to detect magnetic fields present within stores.

09 CUSTOM DESIGNS

Custom designs, such as the approach used in the Amazon Go store.

These techniques are expected to evolve over time. The best accuracy is achievable by combining several of these approaches together. Traffic flow analysis needs roughly 2m accuracy, enough to assess which aisle a shopper is standing in. And a customer-facing store guide may require 1m accuracy to be truly valuable to the shopper and guide them right to the product they are looking for.

AMAZON GO

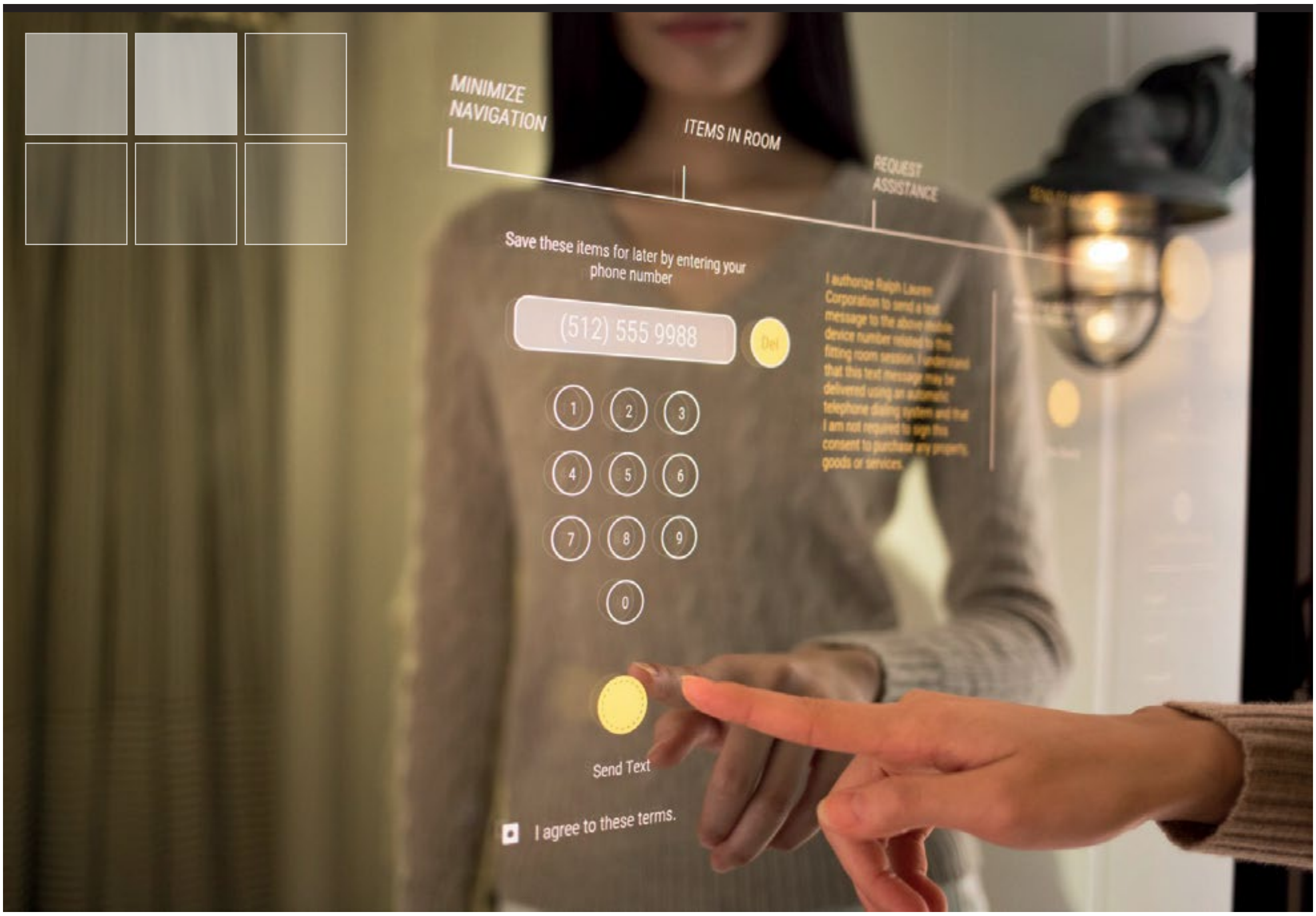
Amazon has recently opened their first Amazon Go store, where shoppers can select the items they want and then leave without having to go through a checkout.

INSTEAD, THE STORE uses a mix of computer vision, deep learning algorithms and sensor fusion (where data from several different sensors are "fused" to compute something more than could be determined by any one sensor alone) to identify a person and their purchases. Customers must scan an app to enter the store, after which everything they take is logged via camera and shelf sensors and placed in a virtual cart. The system then bills the customer's Amazon account when they leave.

amazon.com/go

TECHNIQUES USED IN FULFILLING THIS CONCEPT INCLUDE:

- Customers check in by scanning their smartphone's Amazon Go app's QR code
- The store tracks them with dozens of ceiling-suspended sensors
- A combination of video feeds with image analysis and laser arrays is used to identify people and items in the store. The technology is like that used in self-driving cars.
- Data from these sensors and video feeds is aggregated and combined with machine learning, resulting in a package that Amazon calls 'Just walk out technology'.
- If a shopper picks up a carton of milk, the technology adds it to their virtual cart. It also removes it if it is returned to the shelf.
- Amazon charges their account when they leave the store.
- One shopper tested the technology by turning off his phone, taking items and returning them to the wrong place. The app still tallied his items correctly.



CLOTHING STORES & MAGIC MIRRORS

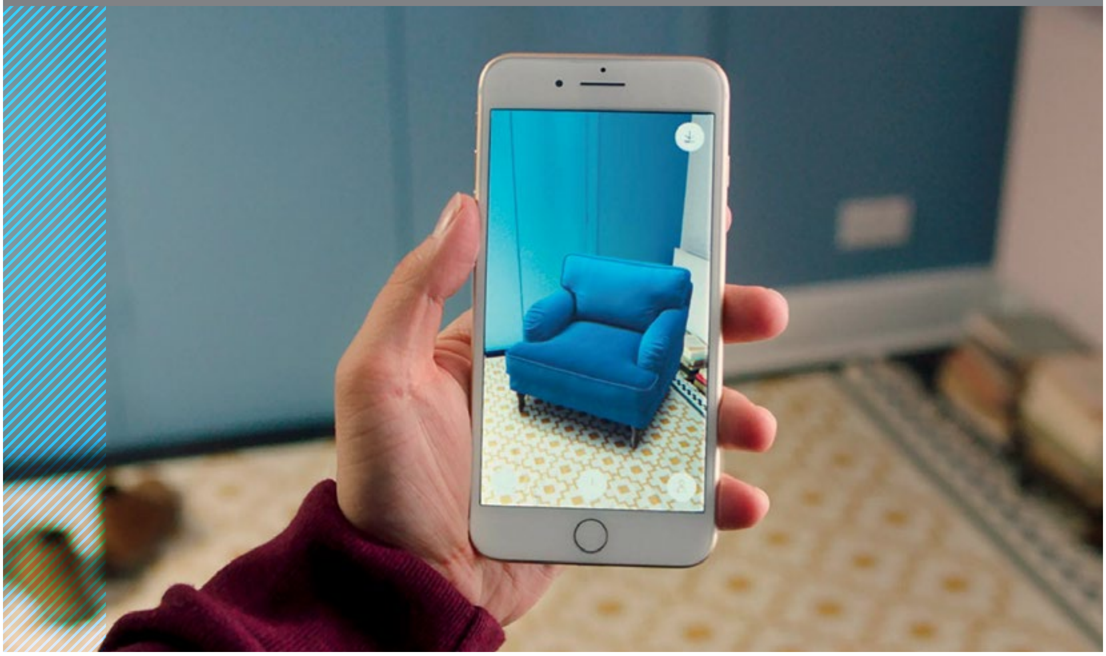
Since e-commerce began threatening stores last decade, retailers have been trying to make their locations operate more like the web.

ONE PLACE WHERE IMprovements can be made is the fitting room, as shoppers who use this are seven times more likely to make a purchase than those who simply browse the sales floor, according to research by Alert Tech.

As one response, Oak Labs, a startup founded in 2015 by former eBay executives, has developed a fitting room mirror that offers an interactive experience. A woman enters with jeans and a blouse. Sensors read the radio-frequency ID tags on the clothes and display the items on a touchscreen embedded behind the glass.

A recommendation engine – like those ubiquitous online ones – suggests complementary pieces such as shoes and a belt. The customer can choose a language other than English and adjust the lighting (options might include 'dusk' and 'club'). If an item doesn't fit or the colour isn't right, she taps the mirror, which triggers a request on store clerks' mobile devices.

zivelo.com



IKEA STRIVE TO MAKE GOOD DESIGN ACCESSIBLE TO EVERYBODY. THEIR NEW AUGMENTED REALITY APP, IKEA PLACE, REPRESENTS THE LATEST EFFORT TOWARDS THIS AMBITION, TO PERHAPS CHANGE THE WAY PEOPLE BUY FURNITURE FOREVER.

THE FURNITURE INDUSTRY

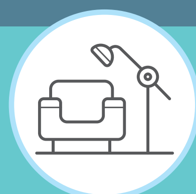
WHILE FURNITURE can be ordered online just as easily as food or clothes, it's not nearly as easy to return if it doesn't look right in its chosen position. Yet, according to IBISWorld, 15% of the $70 billion US furniture market has moved online.

An article in Forbes describes how the industry is achieving this through augmented reality, 3D rendering and computer vision tools that let customers see how a piece looks in a room.

Augmented reality allows customers to virtually 'try out' furniture. For example, Pottery Barn's 3D Room View app for iOS allows customers to instantly stage new furniture items at home using their iPhone or iPad. Customers can see an augmented reality view of their room and drop in full sets of furniture for consideration. Companies like Wayfair, IKEA and Houzz have also implemented augmented reality solutions for furniture "try-on," but Williams-Sonoma Inc (WSI) – which owns Pottery Barn and other stores – has even bigger plans for the technology with the acquisition of Outward, an augmented reality startup. One plan involves adding more assets for consumers to virtually stage and enabling customers to 'try out' multiple furniture brands together.

WSI has employed Outward to generate photorealistic renderings of their products, which they used to replace some of the photography across the WSI brands. Outward also provided 3D renderings that enabled 360-degree views of WSI products, so customers can see the furnishings from all sides.

outwardinc.com



3D furniture 'try-ons' are also available from Modsy, another visualisation company. Their app allows users to take a few smartphone pictures of their room, including clutter, and receive a 3D model of the room, rendered as empty. Styling tools then allow viewing of multiple layout options and different products. Human Style Advisors can provide help if needed.

modsy.com

CONCLUSION

Retailers are facing over-capacity in their sector and fierce competition from online shopping channels.

Smart retailing is a set of hardware and software technologies that allow retailers to fight back, by offering shoppers better experiences and by revealing deeper insights into their daily operations and how they can be improved.

In this article we have seen in general how smart retailing is being implemented in terms of smart shelf and shopper location. We have then reviewed more specific examples of how smart retail is currently being used – in the Amazon Go shop, a clothing store and a furniture retail application.

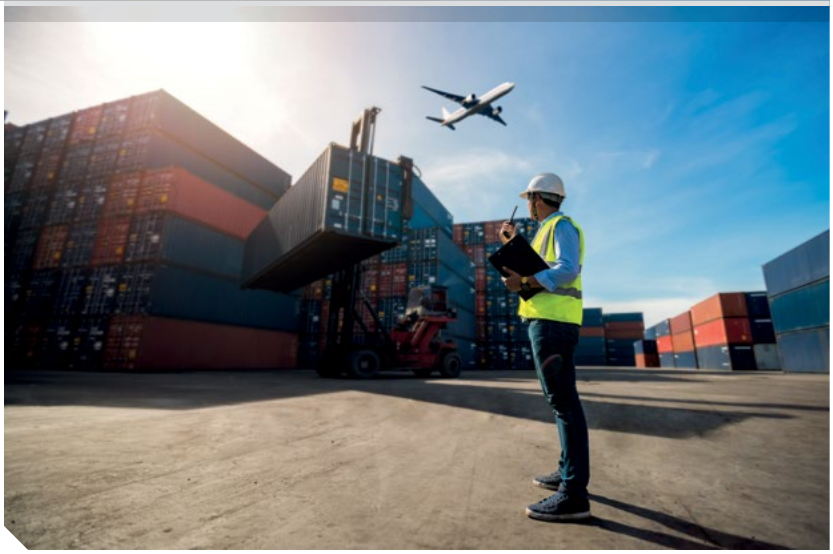
THE IOT'S IMPACT ON SUPPLY CHAIN MANAGEMENT

From a technical viewpoint, it's easy enough to name the benefits of the IoT. Large arrays of low cost, low power, rugged sensors can gather detailed data from any type of natural, industrial or commercial process, while powerful cloud-based computer resources crunch this data to extract actionable information.

BUT HOW CAN ORganisations best exploit this unprecedently powerful and fast-evolving tool? How can they gain deep new insights that will allow them to not only improve their service to their customers, but also the products they are manufacturing – in terms of both quality and alignment with what the customer really wants?

In this article we examine this question in terms of a resource that every business must have – a supply chain. While this is obvious where physical goods are involved, in the IoT world it's also true when services or software products are being supplied.

We start by defining what a supply chain has come to mean today, then look at the elements within this chain and how these can, as suggested above, gain new insights that allow suppliers to improve both their services and their products.



TODAY'S SUPPLY CHAINS

For manufacturing companies, whether their product is apparel, computers or something else, the supply chain starts with their raw material and component suppliers.

Buffering between these incoming goods and the company's production schedule is handled by a smart warehouse working with a flexible and smart production line. Finished goods then travel from the manufacturing plant to the company's customers, who would typically be retail outlets or fulfilment warehouses. From here, the chain fans out to single shipments for individual end-users.

In pre-IoT days, the process would stop there. Apart from asking for customer feedback, which is usually patchy and limited, suppliers had no real visibility of what happened to their goods after end customer delivery. How did their users get on with them, did they meet their expectations and how could they be improved? How about when goods are consumed – for example, spikes in vending machine soft drink sales before a football match or popular TV programme.

Now we'll take a closer look at how the IoT is helping businesses get more from their supply chain – firstly in improving track and trace, product quality monitoring and enabling granularity of customer choice, and then in gaining visibility of events after delivery to the end customer – and how this can feed back ultimately into an improved customer experience.

UPPING THE GAME

FASTER, MORE PERSONALISED DELIVERIES

IN A RECENT, WELL-publicised move, Amazon acquired Whole Foods for $13.7b. This acquisition makes perfect logical sense; while Amazon has succeeded in dramatically reducing delivery times compared with competitive offerings, it was still challenged to complete deliveries quickly enough to keep perishable food fresh.

To achieve this, it needed a presence closer to its customers – and Whole Foods provided the solution. Its hundreds of stores offer a hyper-local presence in areas with the greatest density of high net worth individuals, so providing a perfect complement to Amazon's on-line-driven delivery machine.

While this is great news for customers, it increases pressure on competing suppliers who must now comply with a new level of expectations. In fact, this is just one aspect of today's heightened expectations; customers want their products not only to arrive fast, but also to be configured exactly to their individual specification – and these requirements are typically set against a background of high production volumes. This trend comes from the retail sector, which has for a while been rolling out mobile apps that offer more tailored product choices. Sportswear maker Adidas, for example, has created custom product lines that allow consumers to specify their own variations on the standard SKU (Stock Keeping Unit).

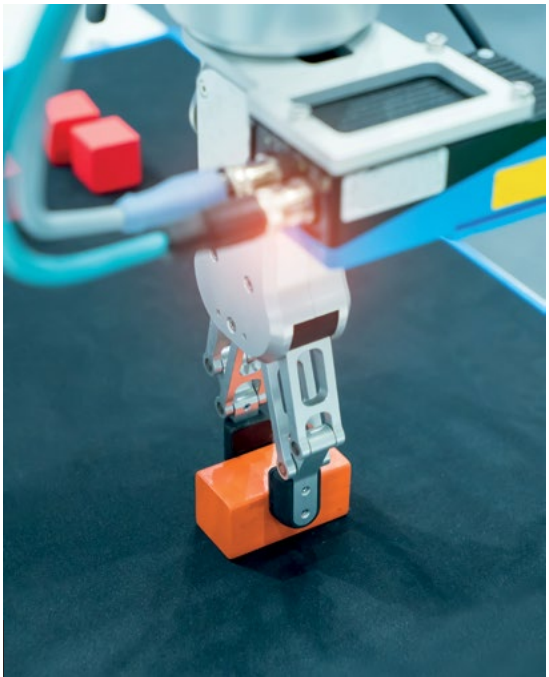
Instead of a conventional purchase orders for tens of thousands of units at a time, those orders come into GT Nexus – a cloud-based collaboration platform used by Adidas – for single units, each with a custom bill of materials. It passes the order to the factory that makes the shoe, and instead of leaving the assembly line with just a SKU barcode, it also has the information needed to ship it to the customer, whether by sea or air. This calls for a so-called bimodal supply chain; optimised both for containers, and for single units of one.

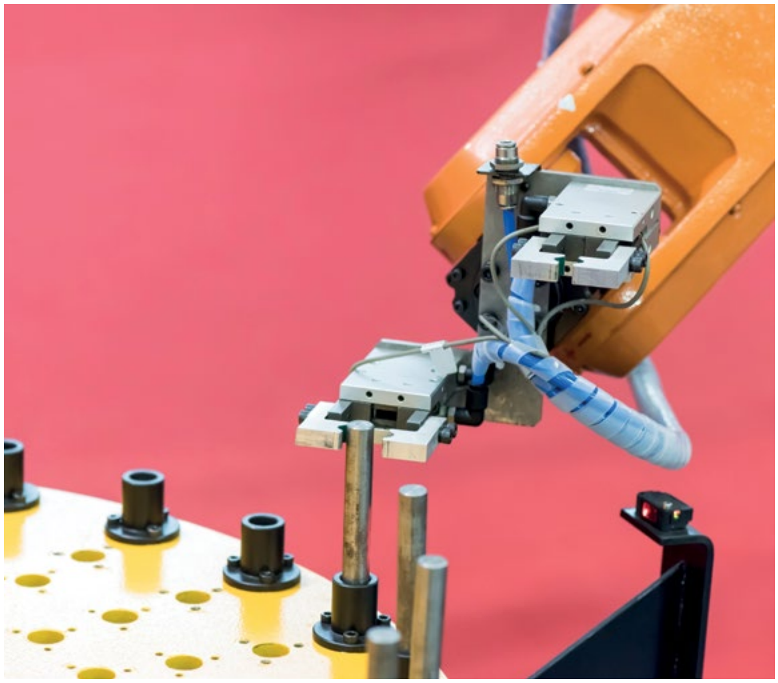
This multimodal flexibility is coming to the B2B world too, as individuals buying the consumer goods are also managers in industrial companies, and bring their expectations with them. It's a generic requirement, equally applicable across electronics, food & beverage, healthcare & pharmaceutical, automotive and other diverse industries. Implementing greater flexibility at speed often means re-evaluating how the supply chain is organised, because achieving these objectives may need a more modular approach. For example, a heavy equipment manufacturer may decide to build an incomplete base unit that ships from its factory, and then add certain parts to finish it off at a more local facility to meet individual customer specifications.

Segmenting the bill of materials across the supply chain in that way demands greater visibility. Instead of tracking entire container loads from the point of origin to a single destination, it may mean co-ordinating multiple journeys of individual items. That demands more instrumentation as units move through the supply chain, according to GT Nexus president Kurt Cavano. The company is involved in projects using IoT technology to provide what they call hyper-granular visibility into the supply chain; down to unit-of-one visibility, like the Adidas example. In their vision of the future, the supply chain becomes a continuous, real time process rather than a series of discrete steps.

From the viewpoint of a manufacturer or distributor, the supply chain comprises the warehouse and routes to the production line or order fulfilment floor, and the land, sea and air routes between the warehouse, suppliers, customers and end-users. In today's complex, time-sensitive environment, the key challenges are how to track and trace products as they move through the chain, and how to ensure perishable food, pharmaceutical and other items remain fresh en route. Below, we look at these issues, and how IoT technology is being deployed to come up with solutions to meet modern realities.

gtnexus.com





forwardermagazine.com/ask-the-experts/smart-manufacturing-the-connected-supply-chain/

INDUSTRIAL ROBOTS ON THE FACTORY FLOOR

SMART MANUFACTURING & THE SUPPLY CHAIN

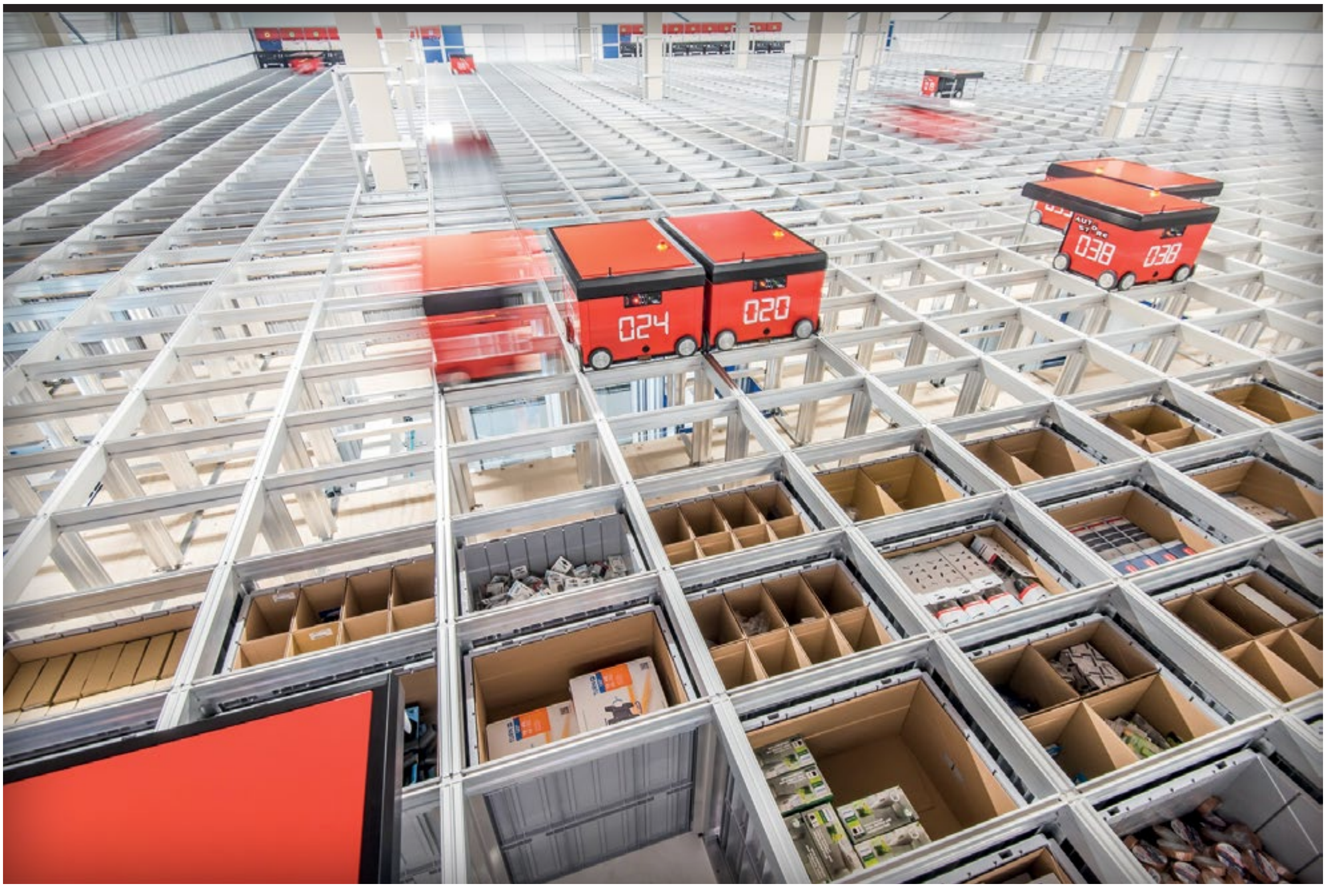
Demands on the supply chain are driven by its manufacturing 'customers'. In fact, the two areas are becoming increasingly integrated and interdependent.

IN A FORWARDER Magazine article, Lars Mohr Jensen, product manager at Gatehouse Logistics, discusses Industry 4.0, where manufacturing becomes intelligent. All individual steps in the production process will be fully connected and integrated. This will impact all planning, production and logistics processes in and around the factory, with processes driven by market needs for production cost reduction, faster time-to-market, mass production of individually configured products, and last-minute order changes. The IoT is effecting these developments by adding sensors to everything and connecting all in the manufacturing and supply chain.

In the car industry, for example, before any car is built, it is assigned a sensor tag, which can be assigned to a specific customer. The car then tells the robots along the production line how to build it. So, if a customer wants to change the specification for a satnav, they can – but it will impact on stock, on satnav suppliers and the whole smart supply chain.

Transparency in the supply chain will be central to every smart factory in every corner of the world so that all know what goods are in transit and when they will be received.

But the smart logistics chain extends far beyond positional information of goods. It extends to conditional monitoring of data concerning every item en route to a smart factory. A smart factory needs to know if any satnav has been damaged when a truck went over a speed calmer, or if any have been exposed to excessively high temperatures or humidity, or other damaging circumstances in a trailer. This calls for islands of information from diverse platforms and systems being securely and transparently connected into one data cloud.



AN INNOVATIVE SMART WAREHOUSE SOLUTION

We have mentioned today's requirement for granularity of choice and efficient product handling in a fast, high volume production environment. One company with such requirements is Texas Instruments, whose Singapore-based Product Distribution Centre (PDC), with a capacity for storing 500 million semiconductors, was becoming overstretched.

IN RESPONSE, TI INstalled a SwissLog AutoStore automated storage and order picking system that increases capacity to 2 billion parts within the same floor space. Productivity has increased by 40%, while inventory visibility and accuracy has been vastly improved.

Spanning 7,500 m² of the 20,000 m² facility, the AutoStore system comprises a massive three-dimensional grid measuring 65m × 18m × 5.4m. The grid, which accommodates up to 63,000 bins to provide its 2 billion component capacity is 108 rows wide, 38 rows deep and is the height of 16 bins. Without need of aisles for movement of people and products, it offers significant space-saving.

Thirty-six robots ply the top of the grid to both store and retrieve products, based on orders placed through warehouse management software known as the AutoStore Control System (ACS). The ACS controls the entire inventory flow into and out of the AutoStore grid. Full visibility at any time is maintained as each item is electronically tagged. Backend information built into the system allows the robots to pick inventory based on the specific requirements of TI's customers – for example, retrieving items manufactured within a specific date range.

More than 800 metres of light goods conveyor system connect the AutoStore grid to receiving and shipping areas, allowing for a swift flow of inbound and outbound goods within the PDC. Products arrive from 20 inbound countries and orders are consolidated and shipped to 54 outbound countries, complete with country-specific labelling created at the facility in Singapore.

autostoresystem.com

TRUCKS FORM PART OF A COMPLEX, TIME-SENSITIVE LOGISTICS NETWORK.

DIGITIZED SUPPLY CHAINS **OVER LAND & SEA**

We have discussed how warehouse automation can supply a production line or distribution centre with customer-specific production kits at speed and in high volumes.

HOWEVER, SUCH warehouses depend in turn on an effective long-distance logistics network that can handle all the complexities associated with the large numbers of suppliers, shippers and vehicles, component volumes and types, large distances and multitude of regions or countries where suppliers are located. It must also be resilient enough to handle unwanted events such as severe weather, theft, road closures, dock strikes, and human error.

There are issues of complexity for manufacturers of products such as cars or computers that require large lists of components. For food and pharmaceutical suppliers, timing is critical as their products can spoil rapidly if they suffer unexpected shipping delays.

Therefore, the challenge is to provide a logistics system that overcomes these issues while handling the fragmentation arising from the multitude of unrelated suppliers, shippers and other factors as mentioned.

One approach, described in another article, employs Intel's Smart Freight Technology, which uses IoT to bring more visibility to freight movement by attaching sensors to individual freight items, and vehicle-mounted gateways for tracking. Operators have a real-time view of where their products really are, not where a bar code scan thinks they might be.

But wouldn't it be great if there were also a powerful resource to correctly monitor, track, correlate and provide transparency on all transactions from all participants – no matter how many there were, and how complex the trail of transactions? IBM and IT business solutions company AOS SAS have come up with a solution that integrates IBM's Blockchain and Watson IoT. Blockchain is a shared, immutable ledger for transactions. It is large-scale, secure and resistant to fraud and error because it runs on multiple machines, with no single owner.

In the IBM blockchain supply chain application, relevant information is captured directly from sensors in the trucks, and entered into the blockchain, creating a single, shared repository that all authorised participants can access and which can only be altered by consensus from all parties. Input and output weight are captured to define available capacity, in addition to identifying which silo and person will carry the load. The data is then correlated against external information, such as weather, humidity, temperature and the driver's data, providing customers with a much more accurate delivery time estimate.

Once the truck leaves the distribution point, an automatic message is sent to the customer, informing them about the load, weight and estimated time of arrival. If part of the delivery is returned, the invoicing can be automated depending on the actual load delivered. Also, through the sensors located on the trucks, an information repository is generated, which tracks all the exchanges, stops and transactions made by each truck and its respective load, from the distribution point to the final customer. This heightened level of transparency can help increase accountability between shippers and their customers, promoting the flow of business.

PERISHABLE FOOD NEEDS FAST AND CAREFUL TRANSIT.

HOW CUSTOMER FEEDBACK REDUCES LOSSES IN THE PERISHABLE FOOD SUPPLY CHAIN

In a Customer Experience Report, Allen Proithis, president and co-founder of Internet of Things company wot.io, describes how combining IoT technology with customer feedback can improve product quality, for example by identifying and eliminating problems related to food spoilage during transit.

HE EXPLAINS: "IMagine that a call centre worker can pull up robust, real-time data on the supply chain that a product traveled from production to customer. Connected systems on the product floor, sensors in delivery trucks and in-store monitoring can give a clear picture of exactly that single product experience – and ultimately, identify where something went wrong, such as sitting on the truck too long, that caused multiple customer complaints," he said.

He cited the example of a caller complaining about a food product. The IoT, he said, can help you see exactly the path from farm to table so that the call centre agent knows, for example, that the product was sitting on the truck for longer than it should have been. "It allows you to track a product through its entire lifecycle," Proithis said. "This means that when a customer contacts an agent the information available is not just account and purchase history but the history of the product or service purchased."

wot.io

CUSTOMER FEEDBACK

AFTER THE PRODUCT REACHES THE CUSTOMER

USING FEEDBACK TO IMPROVE SERVICE AND DESIGN...

AN ARTICLE BY CITO Research describes how the IoT is shaping the future of customer experience and product development, by vastly accelerating product R&D. By using sensor, diagnostic, and user interaction data from devices, companies get full product transparency.

By seeing how customers are using their products, businesses can quickly update features or adjust future models to more closely align with customer desires and behaviours. They can also better anticipate where consumer preferences are going in the future. This insight is invaluable – rather than going through tedious trial and error, companies can know in real time what is working and what is not, enabling organizations to make data-driven decisions and immediately react to correct or adjust issues. This leads to better product design–both now and in the future. For instance, iRhythm, a manufacturer of patches that can detect heart problems, leverages its devices to better understand use and ensure that its products operate as intended.

Customer service improves with access to this level of detail. Proactive notification of customers affected by an outage or affected device changes the paradigm of customer service. Companies can also then better position their customer support centres to allow more immediate service, reducing costs and appealing customers simultaneously.

This virtuous feedback loop extends to the channels and methods organizations can use to interact with their customers. With the data from connected devices, companies can better understand and predict their customers' preferences. Thus, rather than creating a general, one size-fits-all marketing strategy, advertisers and marketers can reach individual segments of their customer base. So instead of flooding all customers with the same offer, marketing teams can create personalized offers that keep the customer engaged and satisfied with the product.

citoresearch.com

AN INTEGRATED APPROACH TO CUSTOMER SATISFACTION

In an article entitled 'How Your Supply Chain Benefits From IoT', Glenn Johnson, Senior VP, Magic Software Enterprises Americas, describes a scenario where IoT platforms can be integrated to provide a seamless customer experience.

He says: "Imagine your company bought you a mobile phone four years ago, and the charger is failing due to a badly worn cord. The mobile phone detects the intermittence of the electrical signal and sends an alert to the integration platform, which routes communications to the e-commerce, PLM, and ERP systems.

Your company's purchasing agent then receives a replacement order form automatically from the marketing automation system, and the product manager receives data in the PLM system informing a decision to improve future models. The e-commerce system receives the approved order, and the integration platform triggers the ERP system to record the transaction and the logistics system to ship it to your office.

You receive the package with a message, "Your mobile phone charger is about to fail. Here is the replacement." Upon delivery confirmation, the integration hub then triggers the CRM system to send you a thank-you note for the order, and records responses to a customer satisfaction survey.""

magicsoftware.com

CONCLUSION

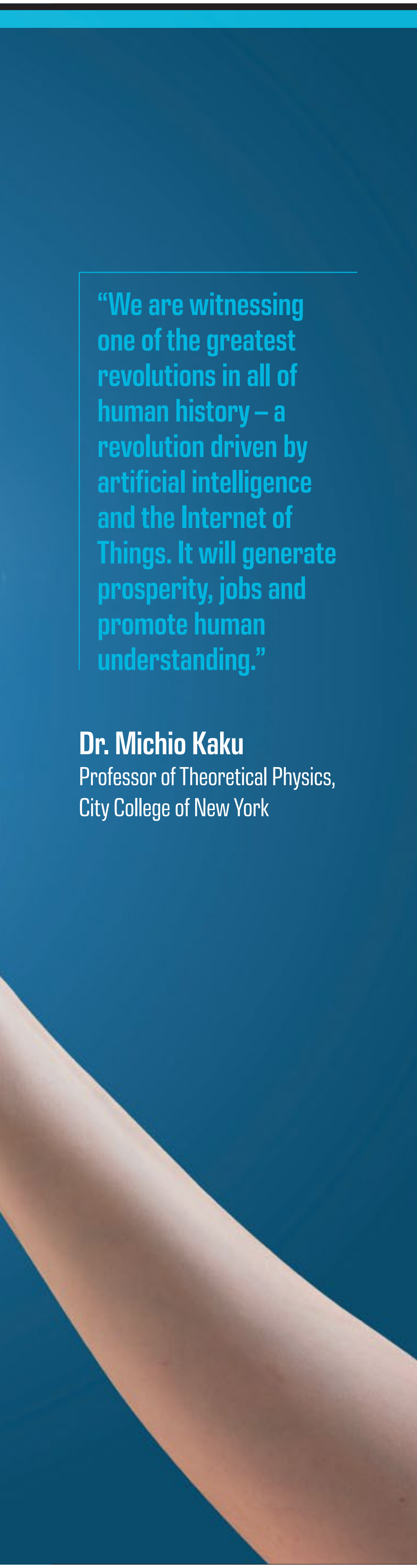
It's a safe bet that business owners will want to improve the quality of their products and their customers' experience in purchasing them; these factors will improve reputation as well as profitability. This article has shown how they can achieve both by adding IoT capability to their supply chain.

Using sensors for track, trace and environmental condition monitoring will ensure users enjoy timely delivery of the right product in good condition, while ongoing monitoring and feedback after delivery will give suppliers deeper insight into users' experience with their products and transactions, and how these can be improved.

AI'S PLACE IN THE IOT INFRASTRUCTURE

ARTIFICIAL INTELligence, or AI, is a term first coined by John McCarthy, a cognitive scientist – who became known as the father of Artificial Intelligence – in 1955, to describe machines that could reason like a human. Since then, fed by the growing powers of enabling hardware and software technologies, and the Internet, both AI and the IoT have been increasingly impacting our daily lives. And in the opinion of many, this impact could become far more profound in the not too distant future.

This article starts by looking at what AI is, and what it could become. It then returns to the present, and considers the current relationship between AI and the IoT, and how this is bringing benefits at all levels. We finish with a roadmap that defines the possible future stages of AI development.



> "We are witnessing one of the greatest revolutions in all of human history – a revolution driven by artificial intelligence and the Internet of Things. It will generate prosperity, jobs and promote human understanding."

Dr. Michio Kaku
Professor of Theoretical Physics, City College of New York

WHAT IS ARTIFICIAL INTELLIGENCE?

At its simplest definition, Artificial Intelligence (AI) is about the development of computers that can do things normally done by people. The Turing Test, developed by Alan Turing back in 1950, addressed this issue; it recognised that machines may be able to exhibit intelligent behaviour indistinguishable from that of a human.

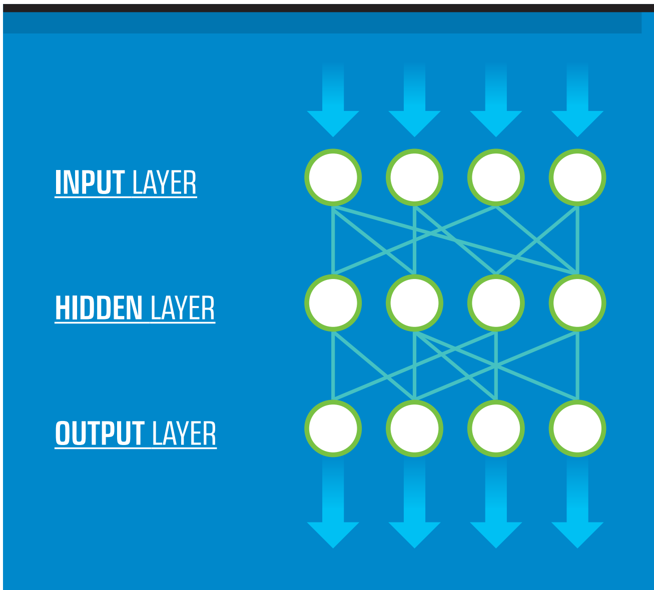
SINCE THEN, MAchine processing capability has grown steadily; fulfilling the Moore's Law prediction that computing power would double every two years. AI is now about computers' ever-increasing ability to search and recognise patterns on continuously growing stores of data. It also addresses two more factors; how an AI system can continuously learn from its incoming data and improve accordingly; and how it can act on its own conclusions without reference to humans.

AI systems, whether we realise it or not, have become part of our daily lives. An article in Wired highlights the Google search engine as a prime example of this; each of the billions of searches performed every day repeatedly tutor the search engine's deep-learning AI.

Another example is IBM's Watson, a set of Cloud servers that offer AI services to subscribers such as doctors and hospitals. In one user's opinion, 'Watson will soon be the world's best diagnostician – whether machine or human'.

However, if we allow AI to take over from humans in real-world as well as information applications, designers will have to realise that with greater power comes greater responsibility. Imagine an AI system controlling a large-scale chemical plant, for example. If something goes wrong, the system may decide to destroy part of the plant to prevent further damage and risk to life. Bearing in mind that the system will be making these decisions based on a breadth of data that we maybe cannot assimilate, will we be prepared to grant that autonomy?

ibm.com/watson



NEURAL NETWORK

CHEAP PARALLEL COMPUTING

Thinking is an inherently parallel process, billions of neurons firing simultaneously to create synchronous waves of cortical computation. To build a neural network – the primary architecture of AI software – also requires many different processes to take place simultaneously.

EACH NODE OF A neural network loosely imitates a neuron in the brain–mutually interacting with its neighbours to make sense of the signals it receives. To recognise a spoken word, a program must be able to hear all the phonemes in relation to one another; to identify an image, it needs to see every pixel in the context of the pixels around it–both deeply parallel tasks. But until recently, the typical computer processor could only ping one thing at a time.

This changed with the appearance of graphics chips (GPUs), which specialised in parallel processing to handle the millions of pixel calculations needed every second to satisfy the intensely visual and parallel demands of video games. The real breakthrough came when Andrew Ng and a team at Stanford realized that GPU chips could be paralleled to run neural networks. Today neural nets running on GPUs are routinely used by cloud-enabled companies such as Facebook to identify your friends in photos.

AI'S GROWTH POTENTIAL

AI will pose plenty of big questions like these, while offering enormous and even unimaginable benefits in the future.

In the University of Cambridge's view, AI is likely to significantly impact upon the very functioning of society, posing practical, ethical, legal and security challenges – much of which are not yet fully appreciated or understood. Yet reversing human aging, curing disease and hunger and even mortality and reprogramming the weather to protect the future of life on Earth are just some outcomes that could become possible. The previously-referenced Wired article describes how this potential for startling growth is being created by the emergence of a number of factors.

BIG DATA

Every intelligence has to be taught. A human brain still needs to see a dozen examples before it can distinguish between cats and dogs. That's even more true for artificial minds.

Even the best-programmed computer has to play at least a thousand games of chess before it gets good. However, AI systems can now school themselves from the vast repositories of data across the Net; massive databases, self-tracking, web cookies, online footprints, terabytes of storage, decades of search results and more. Not least is the data that organisations are now capturing and recording about their own operations, whether they involve machines on a production floor, or service personnel recording the results of their site visits.

Imagine a service organization, for example, that keeps its technicians' reports of incidents attended, with notes about both successful and failed repair attempts. Over time these would build up into a database of many thousand repair scenarios; AI analytic software could continuously process this data, spot correlations, learn, and generate ever-better and more insightful recommendations for ongoing technician support.

BETTER ALGORITHMS

Digital neural networks generate huge volumes of data, but computer scientists have had to learn how to manage this to extract useful information.

THE ANSWER HAS been to use a multi-layer approach in which, if a group of bits is recognised as a pattern such as a human eye, the result is passed up to the next level in the neural network for further parsing – at this point, two eyes may be grouped together. If this process is iterated through fifteen levels, it can arrive at recognition of a human face.

In 2006, Geoff Hinton, then at the University of Toronto, made a key tweak to this method, which he dubbed "deep learning". He was able to mathematically optimize results from each layer so that the learning accumulated faster as it proceeded up the stack of layers. Deep-learning algorithms accelerated enormously a few years later when they were ported to GPUs.

The code of deep learning alone is insufficient to generate complex logical thinking, but it is an essential component of all current AIs, including IBM's Watson, Google's search engine, and Facebook's algorithms.

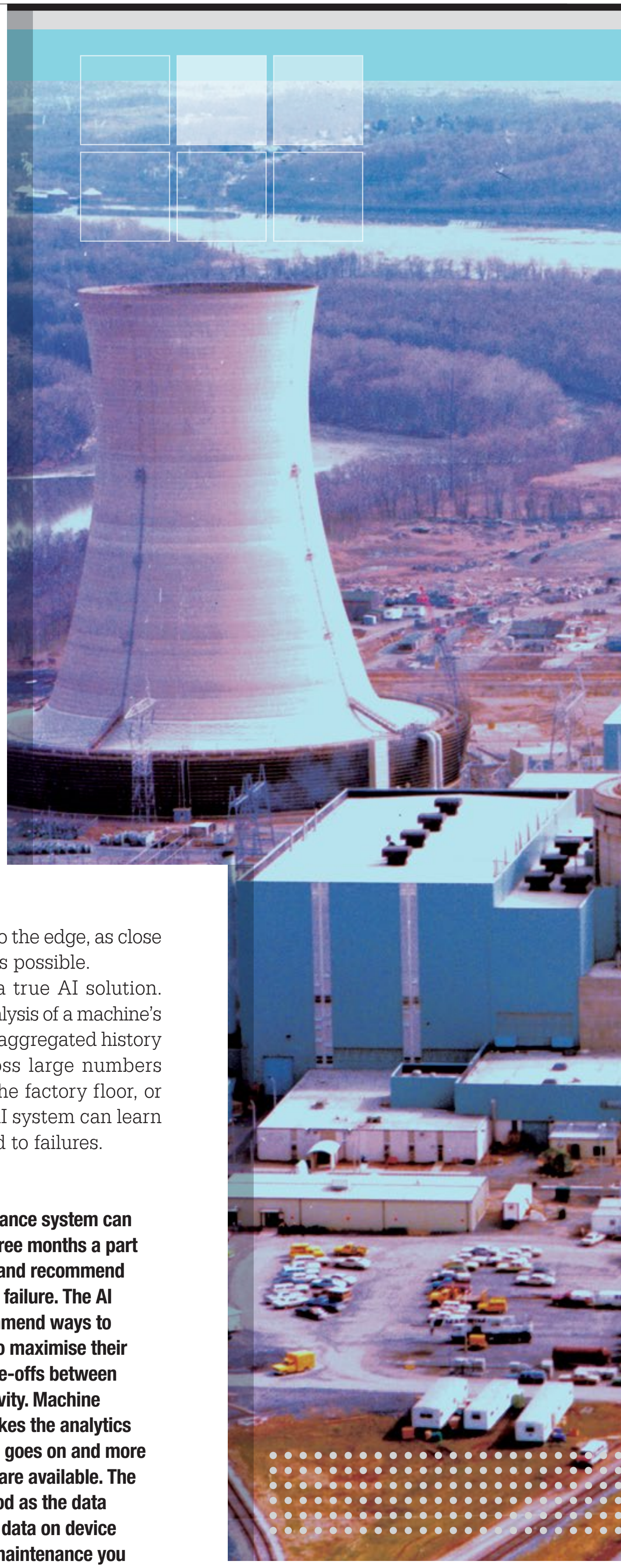
AGI means 'Artificial General Intelligence' and ASI means 'Artificial Super Intelligence', as explained in the AI Roadmap section of this article.

THE RESULT?

POSSIBLY EXPLOSIVE GROWTH...

This perfect storm of parallel computation, bigger data, and deeper algorithms generated the 60-years-in-the-making overnight success of AI.

And this convergence suggests that as long as these technological trends continue – and there's no reason to think they won't – AI will keep improving. In fact, another article by Tim Urban suggests that growth could be explosive due a concept he calls recursive self-improvement. He explains: 'An AI system at a certain level – let's say human village idiot – is programmed with the goal of improving its own intelligence. Once it does, it's smarter – maybe at this point it's at Einstein's level – so now when it works to improve its intelligence, with an Einstein-level intellect, it has an easier time and it can make bigger leaps. These leaps make it much smarter than any human, allowing it to make even bigger leaps. As the leaps grow larger and happen more rapidly, the AGI soars upwards in intelligence and soon reaches the superintelligent level of an ASI system. This is called an Intelligence Explosion – a term coined by Irving John Good in 1965 – and it's the ultimate example of The Law of Accelerating Returns.'



BACK TO THE PRESENT

FACTORY AI & IOT SYSTEMS

We have looked at the possible future of AI, but, naturally, alternative scenarios may unfold – only time will tell. Meanwhile, let's see how AI, especially together with the IoT, is already influencing our world of today.

WITHIN FACTORIES, IT'S POSsible to trace an evolutionary path ending where IoT and AI, through feeding off one another, are improving our ability to understand and manage our industrial processes:

In an industrial plant, data generated by machines on the factory floor can be used to generate simple alerts, such as a warning to check a motor if a temperature sensor reading exceeds a pre-set level.

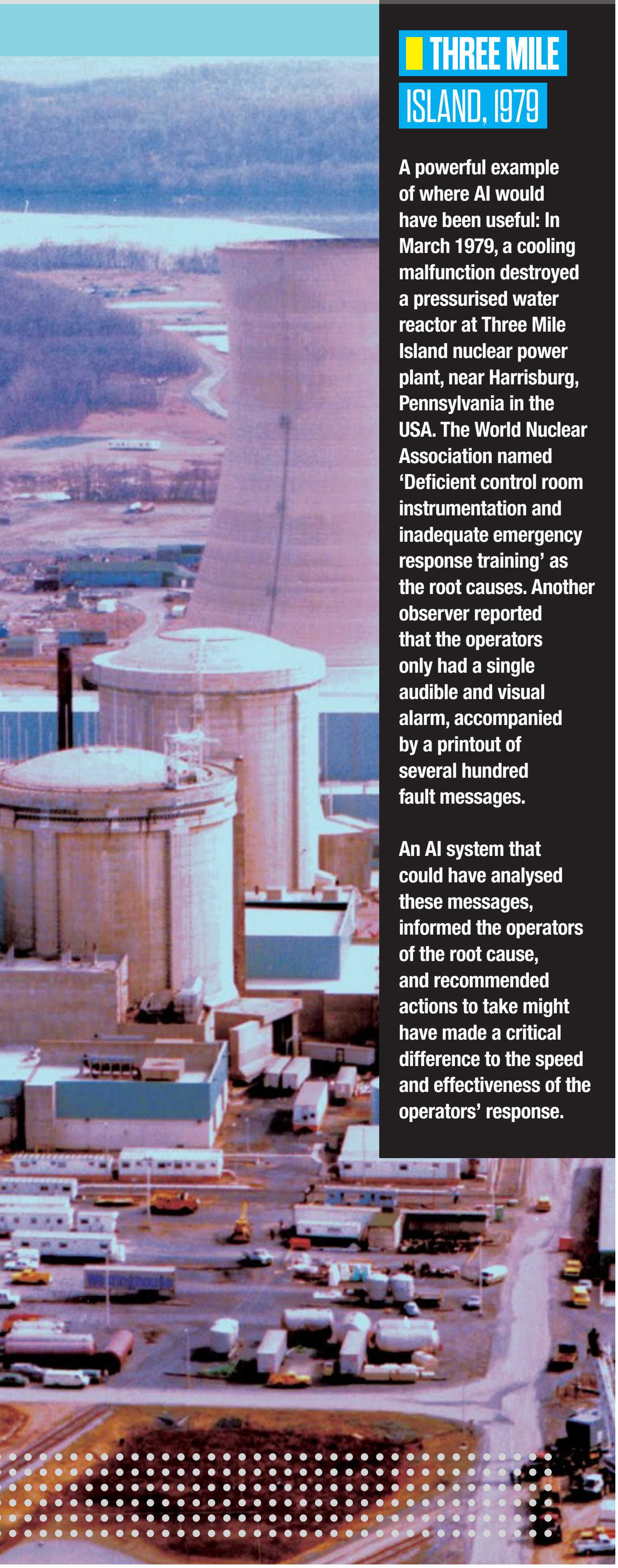
A more sophisticated IoT installation will have large numbers of sensors monitoring various operational aspects; temperature, vibration, current consumption and maybe more. This becomes a Big Data approach, in which all the data is sent to the cloud for a higher level of analysis, together with reporting of historical data and other trends. It also relates to Industry 4.0 architectures, which export factory machine control from local siloed systems, transferring instead to remote, centralised cloud-based facilities.

As this model evolves and grows, the data processing and some other cloud functions are moved to the edge, as close to the data sources as possible.

This can usher in a true AI solution. Based on real-time analysis of a machine's performance, and an aggregated history of performance across large numbers of machines across the factory floor, or many factories, the AI system can learn the patterns that lead to failures.

This predictive maintenance system can forecast that in (say) three months a part will fail if not serviced, and recommend actions to pre-empt the failure. The AI system may also recommend ways to operate the machines to maximise their useful life, offering trade-offs between performance and longevity. Machine learning algorithms makes the analytics system smarter as time goes on and more data-sets and patterns are available. The AI system is only as good as the data it receives, so the more data on device operation, failure, and maintenance you feed into it, the more accurate the predictive analytics system becomes.

THREE MILE ISLAND



THREE MILE ISLAND, 1979

A powerful example of where AI would have been useful: In March 1979, a cooling malfunction destroyed a pressurised water reactor at Three Mile Island nuclear power plant, near Harrisburg, Pennsylvania in the USA. The World Nuclear Association named 'Deficient control room instrumentation and inadequate emergency response training' as the root causes. Another observer reported that the operators only had a single audible and visual alarm, accompanied by a printout of several hundred fault messages.

An AI system that could have analysed these messages, informed the operators of the root cause, and recommended actions to take might have made a critical difference to the speed and effectiveness of the operators' response.

Data is available from many sources in a factory apart from the machines on line:

- Programmable controllers
- Manufacturing execution systems
- Building management systems
- Manual data from human inspection
- Static data such as manufacturer's service recommendations
- External data such as weather conditions
- Geographical data
- Equipment usage history
- Parts composition

CONVERSELY, WITHOUT such AI capability, users simply would not be able to fully realise their IoT installation's potential. The large numbers of sensors characteristic of the IoT would be generating data in volumes that would soon overwhelm human operators or technicians. They would need many hours to correlate and analyse data that could be handled by AI systems in or near real time, if they could do it at all. The AI system could also factor in other variables, such as machine operators' performance, seasonal changes or locations of different factories. If enough data on these is collected over time, the AI analytics can learn further correlations that can convert into actionable information.

Maintenance management using predictive techniques as described will save users money compared with earlier preventive maintenance approaches; these relied on replacing parts sometimes well before the end of their operational life. While preventing failures, this inevitably wastes some of the parts' value.

Further savings can be made by using second-order analytics. For example, deeper analysis can determine the best time to remove the suspect part from service, and which additional repairs, if any, should be performed at the same time.

PRESCRIPTIVE MAINTENANCE ON CLOUD

IBM's Prescriptive Maintenance on Cloud is a software solution that allows reliability engineers to identify and manage asset reliability risks that could adversely affect plant or business operations. It prescribes actions to take based on predictive scoring and identification of factors that positively and negatively influence asset health, and provides a detailed comparison of historical factors affecting asset performance.

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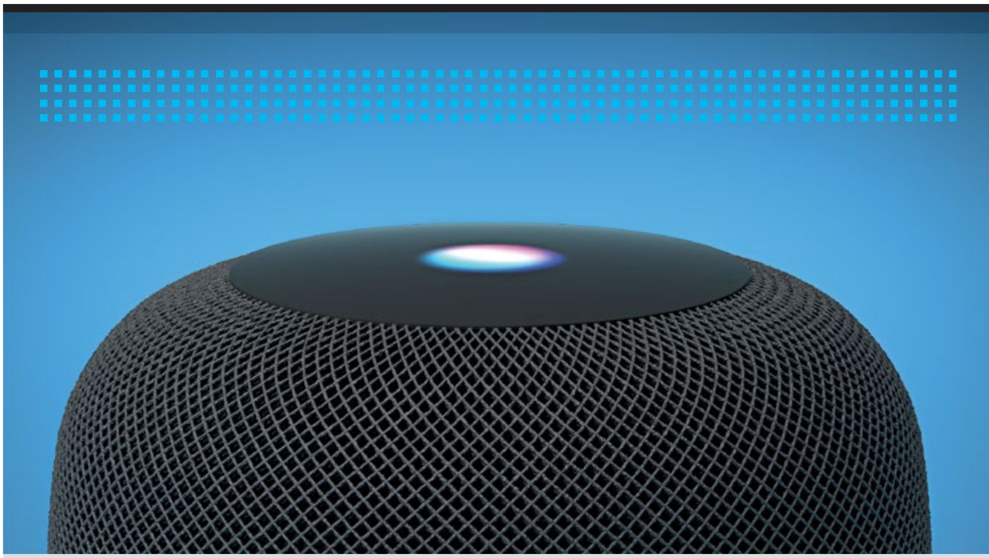


OTHER AI APPLICATIONS
& THEIR BENEFITS

AI's efficiency in distilling information from data translates into significant money-saving benefits. For example, chatbots are expected to save global businesses up to £6bn a year by 2022, according to Juniper Research.

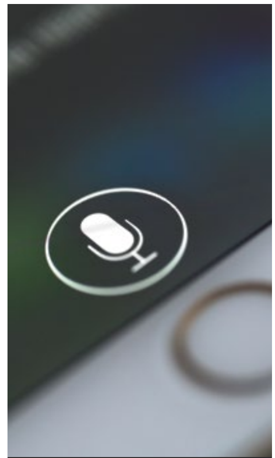
MARC LIEN, DIRECTOR of digital development and applied science at Lloyd's Bank, believes that chatbot technology is significantly augmenting the service from customer support staff. He sees it as extremely powerful in bringing together the entirety of the institution's knowledge base to a colleague in a conversational manner, where and when they want it.

Wide adoption of chatbots is facilitated as data from AI-powered backends can be made available through APIs for any authorised front-end to consume. Integration into apps, websites, or other front-ends can be made easy.

Using AI to extract data from IoT sensors can bring benefits to city dwellers – and provide a platform for further, more holistic improvements to follow. This is being demonstrated by Redwood City's response to the common complaint of insufficient parking availability, despite the proximity of many parking garages that were only about half-full. The California city has set up a pilot project to install vehicle sensors into two of these garages. These not only reveal the available parking spaces and their locations, but also measure traffic flow patterns and help to provide information indicating when the garages are busiest.

This scheme is part of a more ambitious infrastructure plan. The City has launched another pilot project to test autonomous delivery robots. Parking data will also be related to smart lighting systems and connected water meters that can sense future ruptures. The City's council believes that this holistic approach and use of IoT and AI technology is the future for city infrastructures. Additionally, having AI make data-driven decisions on infrastructure and city planning is key to setting up a future where self-driving vehicles can function.

AI is also influencing our lives in more direct, personal ways. We see it at work every day on shopping sites, supplying information into areas like 'Customers who viewed this also viewed…'



SPEECH RECOGNITION

Speech recognition is another major beneficiary of AI. As this technology improves, we can interact with our computers and smart devices faster and more effortlessly. IBM has recently announced that it has achieved a new industry record in conversational speech recognition, with a word error rate of just 5.5%. The software uses deep learning technologies and takes advantage of negative examples as well as learning from positive ones, so it becomes smarter over time and performs better where similar speech patterns are repeated. While this performance is not yet on a par with humans' at 5.1%, it is becoming an increasingly useful contender.

ibm.com/watson

AI NOW & IN THE FUTURE

LET'S LOOK AT A SLIGHTLY FUTURISTIC EXAMPLE, THE HOSPITAL VISIT.

IMAGINE THAT you're visiting your niece in hospital, who's recovering from a hockey accident. On arrival, you're greeted by a digital receptionist like the one shown above.

"Hello Mr Smith, your niece is in bed 5 on Ward 6 – but the orthopaedist will be assessing her in a few minutes. I recommend waiting for a while, so you can discuss the doctor's report with your niece. Meanwhile, why don't you visit our café? It's hot today, and they're serving plenty of cool drinks. I'll send a map to your smartphone, so you can find it easily.

The map also shows the gift shop location, which may be useful, as I can see that you're empty-handed. I'm aware of the traffic congestion on the ring road today, which may have denied you the time to buy a gift elsewhere. One last thing: I see it's nearly a month since you collected your last blood pressure pill prescription – you should collect your next pack as soon as possible, but don't forget that the pharmacy closes at 4:00 pm today"

On arrival with your niece, you can discuss the Doctor's report with her, as well as the feedback from her fitness device. This has been tracking how well she has been following her therapy program, comparing results with historical norms, and highlighting divergence as appropriate.

CONCLUSION

In this article, we have seen how AI, long seen as 'something of the future', is now impacting our daily lives. This is happening within many areas, especially where AI combines with IoT implementations in synergistic partnerships.

We have also looked at how the factors that have been giving AI its growing traction – rapidly increasing computer power, Big Data and improved algorithms – are expected to contribute to further, possibly explosive growth in AI and its impact on our society.

Currently, the lowest level – ANI – exists in many implementations everywhere; in cars, factories, cities, shops and homes, and on our smartphones. AGI development projects are in progress, while ASI remains in the future.

One example of an AGI project is Google's purchase of a UK company called DeepMind. DeepMind is attempting to mimic the biological structure of the human brain with software, to build machines that can learn 'organically' – that is, without human involvement.

DeepMind's research includes systems that they claim are having a major environmental impact by learning how to use vastly less energy in Google's data centres. The company is also collaborating with clinicians in the National Health Service on delivering better care for conditions that affect millions of people worldwide.

deepmind.com

AI ROADMAP

Opinions are varied, but most experts accept three categories of AI development.

ANI ARTIFICIAL NARROW INTELLIGENCE

First intelligence calibre, sometimes referred to as Weak AI. "AI that specializes in one area. There's AI that can beat the world chess champion in chess, but that's the only thing it does."

AGI ARTIFICIAL GENERAL INTELLIGENCE

Second intelligence calibre, sometimes referred to as Strong AI, or Human-level AI. AGI reaches and then passes the intelligence level of a human, meaning it has the ability to "reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly, and learn from experience" as easily as a human.

ASI ARTIFICIAL SUPER INTELLIGENCE

Third intelligence calibre: Oxford philosopher and leading AI thinker Nick Bostrom defines superintelligence as "an intellect that is much smarter than the best human brains in practically every field, including scientific creativity, general wisdom and social skills." Artificial Superintelligence ranges from a computer that's just a little smarter than a human to one that's trillions of times smarter – across the board.

DETERMINING YOUR NEEDS

The following is a list of requirements identified by Cisco IoT experts as important for start-ups and small businesses to know when looking to design for the IoT. There are four important requirements you'll need to establish prior to starting your design:

01 RANGE DISTANCE

02 RADIO FREQUENCY BANDS

03 POWER CONSUMPTION

04 NETWORK TOPOLOGY

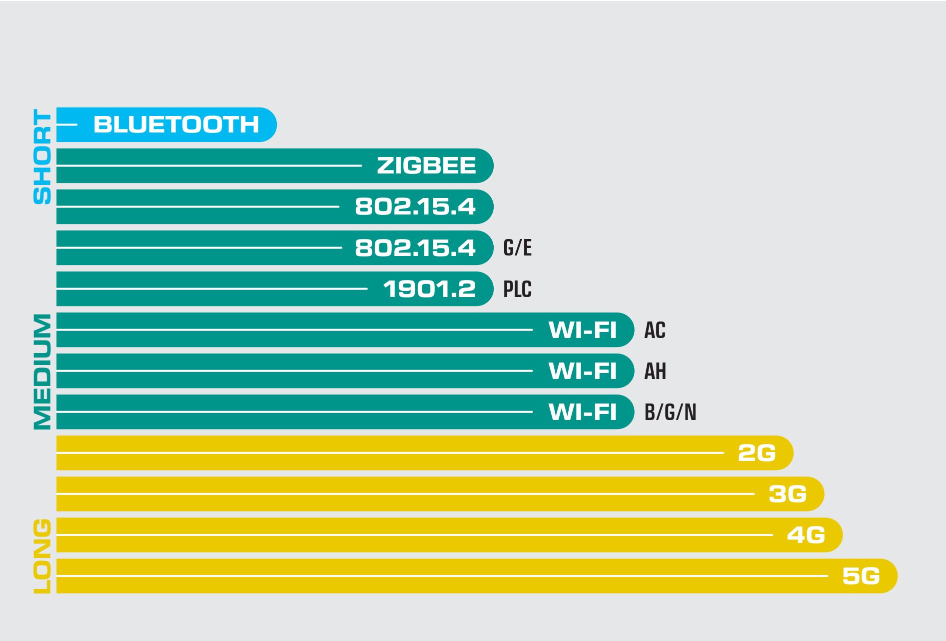
CONNECTING DEVICES TO THE INTERNET OF THINGS

Some projections for the global Internet of Things (IoT) market are that it will grow to $457 billion by 2020, up from $157 billion in 2016 (Forbes, 2017). More recently, Microsoft announced that it will invest $5 billion in the IoT over the next four years (Microsoft IoT, 2018).

OVER THE PAST SIX to eight years, according to IoT Institute, well-known players like Cisco, Intel, Google, and Qualcomm have invested heavily in IoT companies as they work to build out their ecosystems. Given those statistics, it's only rational (and, frankly, essential) to see household device manufacturers continue to design new IoT-enabled products.

However, determining where to start can be a daunting task for start-ups and small businesses. There is currently no regulatory agency to set standards for the IoT, and the variety of communication protocols resembles the American Wild West of the late 1800s.

The good news is that there are certain protocols that seem to be very promising in the IoT marketplace. Some of them are well-known, but others are relatively obscured from the mainstream consciousness.



RADIO FREQUENCY BANDS

Should you opt for your device to connect wirelessly, you'll need to decide whether to use licensed or unlicensed radio frequency bands. Some of the key differences between licensed and unlicensed bands are detailed in the table below.

ORGANIZATIONS SUCH as the International Telecommunication Union (ITU) and Federal Communications Commission (FCC) define and set the regulations and transmission requirements for the licensed radio frequency bands, so the guarantees and protections come from reputable agencies.

It's important to note that the unlicensed bands are regulated, but they do not afford the protections (and thus, better service guarantees) of licensed bands.

	LICENSED RADIO FREQUENCY BANDS	UNLICENSED RADIO FREQUENCY BANDS
Users must subscribe to services to connect IoT devices	Yes	No
Guarantees or protections for better service	Yes	No
Dependent on a service provider	Yes	No
Data delivery rate	Higher	Lower
Ability to go through buildings or around obstacles	Not likely	More likely

RANGE

TO GET YOURSELF STARTED, ASK AND ANSWER TWO QUESTIONS...

01 WHAT IS YOUR DESIRED AREA OF COVERAGE?

02 DO INDOOR & OUTDOOR DEPLOYMENTS NEED TO BE DIFFERENTIATED?

Depending on your needs, the most promising communication technologies are as follows:

SHORT RANGE

Less than 100m distance between two devices

MEDIUM RANGE

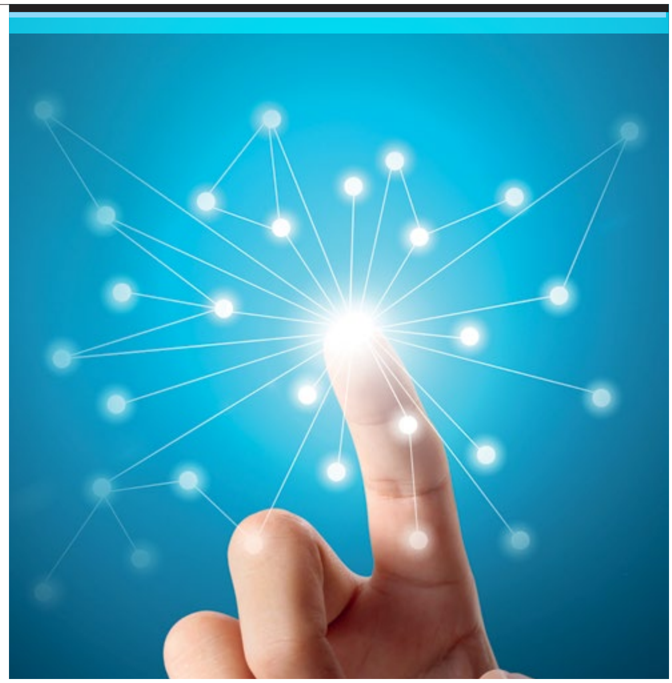
Between 100m and less than 1 mile

LONG RANGE

Distances greater than 1 mile

TOPOLOGY

You'll need to decide the best scheme for your devices to connect with others. At this point, three main topology schemes lead the current IoT landscape.



STAR TOPOLOGY

IN A STAR TOPOLOGY, every node or client connects to a central network device. A common example of this is an in-home entertainment system. In that system, the speakers and the TV (the nodes or clients) all connect to the receiver (the central network device). Our cellular infrastructure also operates on a star topology, whereas our cell phones (clients) all connect to cell towers and a central station (central network device).

PEER-TO-PEER TOPOLOGY

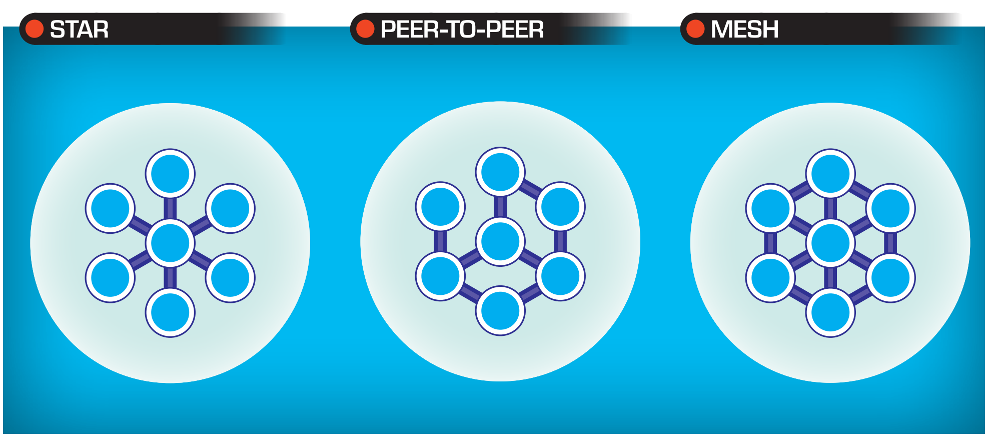
PEER-TO-PEER TOPOLOGY is when each device is interconnected with others and each device may have its own clients linked to itself. In this topology, no central network device is needed.

The most common example is a personal PC connecting over the internet. In this example, files can be shared directly between systems on the network without the need of a central server, with each computer becoming a file server as well as a client.

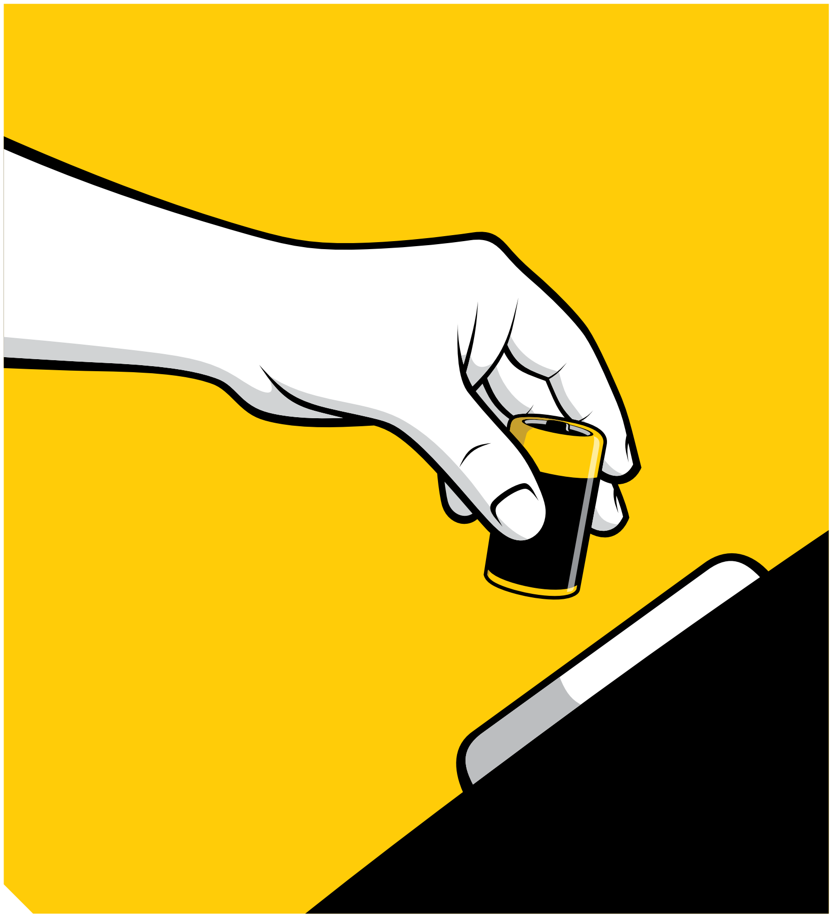
MESH TOPOLOGY

A MESH TOPOLOGY IS an advanced form of peer-to-peer topology. Properly constructed and optimized, it allows devices to communicate and cooperate with each other for maximum data efficiency and battery usage.

One innovative example of a mesh topology is FabFi. Funded by a grant from the National Science Foundation, FabFi is a small-scale, open-source wireless network being developed to transmit wireless Ethernet signals using common building materials and off-the-shelf electronics.



However, there are significant hurdles one must overcome to optimize a mesh topology and implement devices so that they function properly; otherwise, the battery lifetimes can be greatly shortened. One such hurdle is a properly optimized implementation for battery-powered nodes. If not done properly, the battery lifetime is greatly shortened, putting the node at risk for failing in the market.



POWER

POWER CONSUMPTION

Identifying a device's power consumption needs is equally important. For battery-powered devices, an important concept to determine is how often a battery would need to be changed.

If it's too frequently, the device won't succeed in the market. Conversely, if the battery puts out too little power, the device may not have the functionality to succeed in the market. With utility costs becoming a greater focus for product commercialization, power consumption is important to consider for plug-in devices as well. If a new device or set of devices requires a high amount of power to run properly, that extra power cost could turn away cost-conscious consumers and hurt a product's chance of succeeding in the marketplace.

WHERE DO YOU GO NOW?

At Molex, we have engineering resources and industry experts who live on the front lines of IoT development. We published a complimentary Trend Report on the IoT in Home Technology, describing how manufacturers can successfully position themselves for what comes next in the Connected Home.

We encourage you to explore our reach into the connected home marketplace by exploring our Connected Home interactive website, which details technologies used in applications throughout residential properties. From antennas to micro-miniature components and carbon monoxide sensors, we offer solutions suited for the IoT marketplace.

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