⦿ HOKUYO USA

History of Robotics
Industrial Automation

Sensing The Future ⬤

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Robotics

## A look back at the last 100 years

Robots are now deeply involved in industrial processes. Their key role is enhancing factory floors with high precision and efficiency. However, their journey has been long and progressive.

Industrial robots can be traced back to the early 20th century, but only after the mid-1900s did they have a substantial influence over industrial operations. With the passing of years, we humans have made groundbreaking advancements that have redefined robotic potential in manufacturing capabilities, safety standards, and production efficiencies.

Griffith "Bill" P. Taylor's prototype in 1937 was the first robot that worked on pre-programmed patterns capable of automating wooden block stacking. From that to the fine-tuned AI-driven robots of today, industrial robotics has been pivotal to all future industrial applications and aspirations.

This paper explores the rich history of robotics, stressing its evolution from old-school mechanical tools to comprehensive systems with sensors, actuators, and cutting-edge mechanical parts. The paper highlights how robots changed from lifeless tools into programmable, sometimes self-dependent helpers seamlessly integrating with human operators and complex factory infrastructures.

As we go back into the past, looking at the phases that robotic automation has passed through, we will also speculate where current trends and emerging technologies lead the industry. With this knowledge, industry leaders, technologists, and innovators can find their place in the next phase of industrial automation.
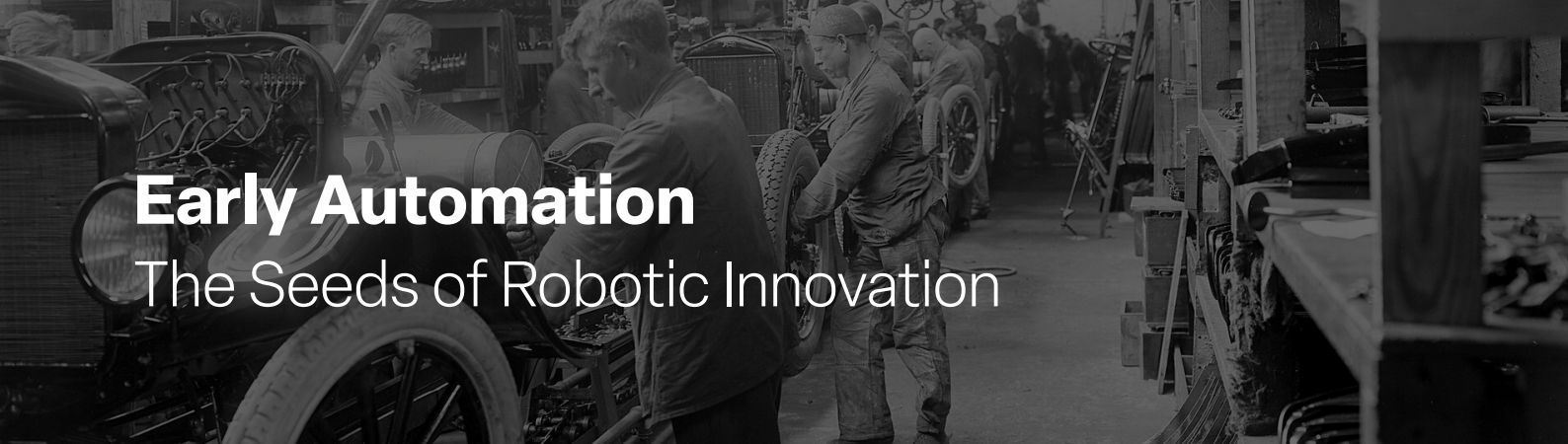
Early Automation
The Seeds of Robotic Innovation

Robotic innovation and the dream to enhance production through technology have come to life through centuries of imagination and conceptualization.

Long before the term 'robot' existed, artificial servants and mechanical companions were often depicted in ancient myths and literary works. Tin Woodman from L. Frank Baum's 1900 classic, The Wonderful Wizard of Oz, is a prominent example. This cyborg highlights early 20th-century society's fascination with merging humans with machines.

With Karel Čapek's play "R.U.R.: Rossum's Universal Robots," the concept of 'robots' emerged more clearly in 1920. The term 'robot' essentially comes from the Czech word robota, which carries the notion of forced labor. This play introduced the world to the idea of synthetic humanoids working in factories while also highlighting the potential efficiencies and existential risks of such autonomous labor.

At the same time, real-world advancements made factory automation more realistic. The Ford Motor Company revolutionized manufacturing in 1913 by introducing an assembly line for car production. This innovation drastically enhanced production efficiency, as it reduced the assembly time for a single car from 12 hours to about one and a half hours. Ford assembly lines were a major, and arguably the first implementation of automation in industrial history that made mechanization of production lines seem like a viable option.

Unsurprisingly, Japan, famously a robot-loving country, played a massive role in pushing the boundaries of what was mechanically possible in manufacturing. Technological advancements in Japan during the 1930s and innovations such as the first micro-switch, protective relays, and precise electrical timers marked significant steps toward modern automation. These components were essential for developing more complex automated systems that later made early robotic technologies exceed their previous limitations.

As history moved toward the mid-20th century, these ideas grew like seeds and eventually sprouted into more capable robotic and automation systems.

The Early Innovations (1930s – 1970s)

Let's begin this journey by highlighting the remarkable developments of the mid-20th century. This was when humans made significant advancements in both conceptual and practical aspects of robots and automation technology.

1937 — Griffith P. Taylor's Early Robotic Inventions

Civil engineer Griffith "Bill" P. Taylor's creation of a crane-like device constructed predominantly from Meccano parts sowed the seeds for a shift that is still improving manufacturing processes.

Running on a single electric motor, this machine includes five axes for movement. This feature enabled it to perform simple, pre-programmed activities like stacking wooden blocks. Even though Taylor's creation did not make it to commercial use, it is an archetypal example of the earliest automation designs and their potential to perform simple tasks.
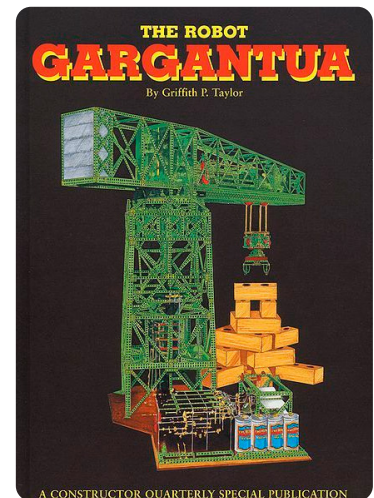
The Robot Gargantua, By Griffith P. Taylor, 1937

1956 — George Devol's Patent and the Birth of Unimation

In 1954, George Devol patented the first digitally operated and programmable robot. Unlike Taylor's automated crane, this innovation managed to unlock robots' true commercial potential. It is safe to say that this patent laid the groundwork for the dawn of the robotics industry.

Devol and Joseph F. Engelberger, also recognized as the "Father of Robotics," founded Unimation in 1956. This was the first company dedicated to the production of industrial robots. This partnership breathed life into robotics as a separate sector and transformed robots from a concept into an applicable technology.
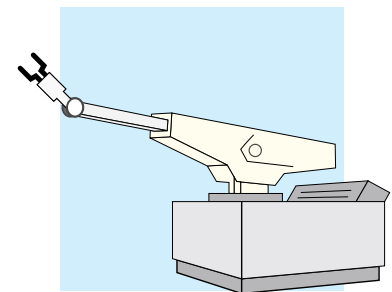
Representation of a polar robot, EBatlleP

1962 — Introduction of UNIMATE

Unimation's greatest achievement was the development of UNIMATE, the world's first industrial robot. This robot was also deployed in the General Motors New Jersey plant in 1962.

UNIMATE was essentially a robotic arm used for material handling, welding, and die-casting tasks. It brought attention to the fact that robots are extremely useful in performing tasks that might put human workers in danger. UNIMATE received a huge amount of public attention due to its ability to automate repetitive and dangerous tasks.

It garnered attention to the point that other manufacturers started showing interest in UNIMATE and robotic automation as viable strategies for industrial applications.
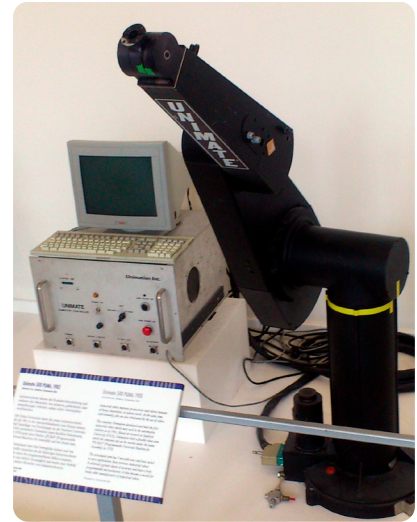
Unimate 500 PUMA - Deutsches Museum

1969 — Victor Scheinman and the Stanford Arm

While Unimation was busy changing people's perceptions of factory automation, simultaneous developments also occurred in the academic domain. Victor Scheinman, a bright mechanical engineering student at Stanford University, invented the Stanford Arm in 1969.

This was an all-electric, six-axis articulated robot that was significantly more advanced than previous models. The Stanford arm offered unparalleled flexibility and precision at that time, which increased the potential applications of robots and took them beyond simple material handling tasks. The Stanford Arm's design made it more suitable for tasks requiring complex and delicate assembly, which was much required in electronics and other flourishing technology sectors.

Scheinman - The Stanford Arm - MIT

These pioneering years built a solid foundation for the development of industrial robotics. By the end of the 1970s, robots began to occupy and enhance manufacturing floors worldwide. These initial technologies are responsible for reshaping the industry and making a huge psychological impact on the masses, highlighting their vast potential to augment human capabilities and improve production.

Technological Advancements and Expansion (1980s - 1990s)

The 80s was the phase of acceptance and rapid integration of robotic technology in manufacturing processes. The influence of early robotic technologies in the past four decades brought the number of industrial robots in America from 200 in 1970 to about 4,000 in 1980. Here are the key advancements that powered the robotic revolution of the 80s and 90s.

4000

+1,900% Increase

200

1970   **1980**
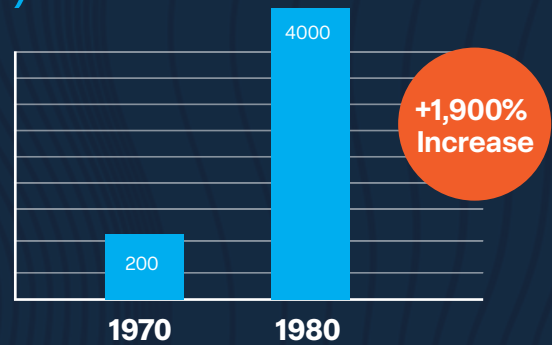
Technobeurs 82 in Utrechtse Jaarbeurs, March 22, 1982

Technological **Advancements** in Robot Design and Functionality

Due to significant enhancements in robot design, material science, and mechanical components, it became possible to develop robots with diverse functionalities.

From simple pick-and-place machines, they transformed into highly sophisticated automated systems capable of performing complex manufacturing tasks. Advancements in the design of robot arm joints were one of the most notable developments in the sector. Motorization of joints allowed smoother and more precise movements. Robots significantly improved in speed and achieved a new level of accuracy in tasks like assembly, painting, and welding. Their newfound capability to perform intricate and delicate operations expanded their roles into production areas that demanded.

Introduction of **PUMA** and Sophisticated Systems

A notable milestone in robotic automation was the development of the Programmable Universal Machine for Assembly (PUMA). First introduced in 1978, this innovation was carried out by Unimation and General Motors.

PUMA was a significantly upgraded industrial robot that involved state-of-the-art technologies from the earlier innovations by Victor Scheinman. It possessed the capability to carry out complex assembly tasks with unparalleled dexterity.

(CMS)Unimat Pumo 500

Gradually, PUMA became a common fixture in electronics manufacturing to perform repeatable tasks with higher precision. Its design principles influenced a generation of robots.

Contributions of Yaskawa and Multi-Axis Systems

Soon after that, in the 1980s, companies like Yaskawa emerged as key players in the new and emerging robotic technology sector. Yaskawa played a key role in robotic evolution by enhancing the functionality of industrial robots by developing robotic controllers and multi-axis systems. They developed systems that allowed operators to control multiple robotic arms at once, which was essentially a breakthrough in production line efficiency.

Their innovation includes the incorporation of advanced servo motors and controllers that enable complex and synchronized movements across multiple axes. This introduced more integrated manufacturing systems and enabled robots to perform tasks with a previously unattainable level of coordination.
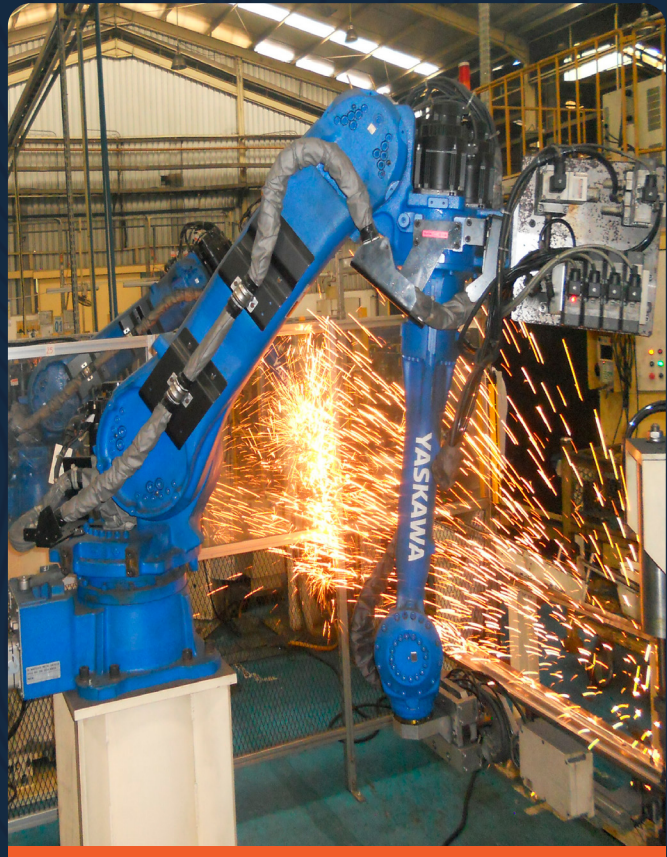
Yaskawa Welding Robot

Global Impact and Industry Adoption

Progress during the 1980s and 1990s expanded the capabilities of industrial robots, resulting in increased adoption of Robotic Process Automation (RPA) across various industries. Apart from the automotive industry, which was essentially the first to adopt RPA, robots also began to play an essential role in sectors such as electronics, pharmaceuticals, and food processing.

One of the key drivers for adoption was realizing that robots could be trusted to work in environments that could be hazardous to humans. Initially used in industries like construction to enhance safety, today we can see robots making work safer in areas like nuclear power and disaster response.

The positive sentiment developed around robotic automation during these decades reshaped manufacturing and paved the way for the next generation of robotic innovation. This includes the integration of artificial intelligence and machine learning technologies with robots in the 2000s. As the capabilities of industrial robots became more evident, they grew to become more and more integral to the modern manufacturing process. This takes us to the next phase, where people started taking industrial automation seriously and moving towards fully automated and optimized production facilities became a clear objective.

The Modern Era of Robotics
(2000s - Present)

Stepping into modern times, industrial robotics have made substantial technological advancements with a significant shift towards integration and collaboration. Since the 2000s, innovations have been directed towards the rise of collaborative robots (cobots) and the seamless integration of advanced sensors. Like other fields, such as material science and business intelligence, robots have benefited immensely from Artificial intelligence (AI) and machine learning (ML). Automation of mechanical processes has become more adaptive and precise, and the interaction between humans and machines on factory floors is much safer.

Rise of Cobots and Integration with Human Tasks

Cobots are one of the most noteworthy robotic innovations of our time. These are machines designed to work alongside human operators or to augment their capabilities. Equipped with advanced force, torque, and proximity sensors, these robots are becoming increasingly safer to work with. Sensors allow them to sense human presence and adapt their operations for optimal safety. This collaboration allows for the precision of robots to augment the cognitive skills of humans to enhance productivity and workplace safety.

Incorporation of Advanced Technologies

Cutting-edge industrial robots working on AI and ML programs can quickly adapt to perform tasks beyond simple programming. These robots learn from the factory environment to gradually improve operations. This intelligence allows robots to increase production efficiency and instantly adapt to factors like market volatility, public demand, and compliance standards. Robots with computer vision and advanced laser object detection systems can handle complex and delicate tasks with a higher degree of precision.

Leading Manufacturers and Innovations

Today, several key players are competing to develop groundbreaking technologies in robotics to take industrial automation to the next level:

ABB continues to lead with innovations in robot software and connectivity. Known for its versatile robots, ABB has worked extensively to improve the flexibility and efficiency of robotic systems. Till now, they have deployed over 400,000 robotic solutions in various industries globally

FANUC offers a wide range of robots that excel at improving precision and speed across various industries and manufacturing processes. In August 2023, FANUC reached the milestone of shipping about 1 million industrial robots.

Known for their system's speed and precision, this company specializes in developing fully integrated industrial robotic solutions for manufacturing lines. Till now, **Yaskawa** has installed more than 500,000 robots worldwide, primarily for handling and assembly tasks.

German manufacturer **KUKA** crafts effective robotic solutions for large enterprises, particularly in the automotive and aerospace industries. They have an industrial robot for every factory automation task. KUKA has positioned itself as an international automation group and has sold over EUR 4 billion units

Denso is one of the world's largest automotive parts manufacturers, known for its high-speed and high-precision small industrial robots. They have installed more than 120,000 robots in the field, which are primarily used in the electronics and auto manufacturing industries

These companies have built exemplary automation solutions and driven robot manufacturers to level up the playing field. The industrial automation sector is more competitive than ever, and progress is imminent.

Impact on the Manufacturing Industry

Automotive Sector

It is a known fact that the automotive industry has been at the forefront of adopting robotics technology. Using articulated robots for welding, painting, and assembly tasks adds immense value to their processes by saving time and ensuring accuracy. Their ability to work continuously increases production rates and round-the-clock functioning, like those in lights-out factories, all while ensuring superior quality. With multiple rotating joints, articulated robots are the best tools for complex but repetitive tasks. New, more advanced articulated arms can now also mimic human arm movements more accurately, providing superior flexibility and reach.

Electronics Manufacturing

The electronics sector requires a high level of precision and miniaturization to develop appliances, components, and tools faultlessly. SCARA (Selective Compliance Assembly Robot Arm) robots are commonly used for this application. These robots excel in assembly operations that require high-speed, precise movements in a limited space. Exceptionally effective for circuit board assembly and component placement, SCARA robots contribute to enhanced productivity while reducing error rates in electronic device manufacturing.
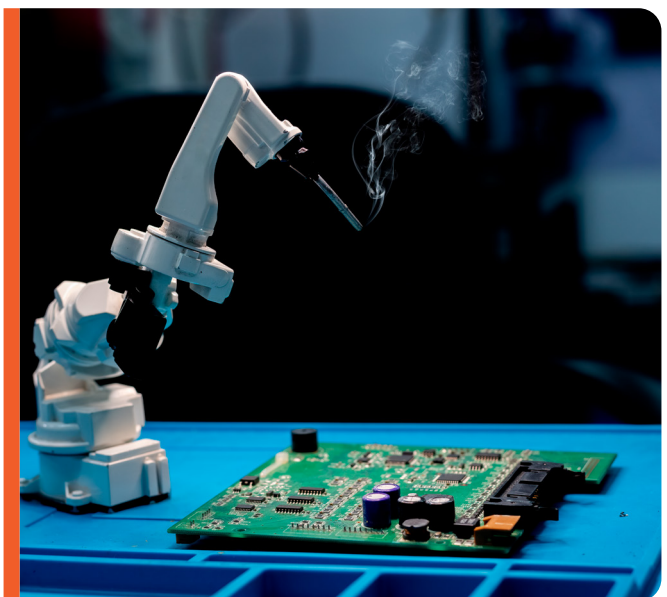
Pharmaceuticals

Over time, the pharmaceutical industry has gained significant advantages from the use of collaborative robots (cobots). The pharmaceutical robotics industry was valued at USD 73.73 million in 2023 and is projected to grow at a CAGR of 9.80% from 2024 to 2030. Alongside human operators, cobots handle sensitive materials and perform repetitive tasks such as filling, packaging, and labeling with high precision. Advanced sensors help them ensure safety and efficiency while maintaining strict hygiene standards.

Food and Beverage

Delta robots are pivotal in the food manufacturing industry as they efficiently and precisely handle the picking and packing of food products. These robots are specifically engineered to delicately manage food items while ensuring rapid and hygienic processing. By doing so, they significantly reduce the risk of contamination and enhance the overall efficiency of the production process. Their streamlined functionality extends to sorting ingredients and packaging finished products, further contributing to improved productivity in food manufacturing.

Heavy Machinery and Metal Fabrication

Highly flexible robotic manufacturing systems have given metal fabricators an agile edge through automation. Today, robots are becoming cross-trained and employ a combination of technologies ranging from deep learning to 3D-printed robot grippers. Six-axis robots are extremely useful in heavy industries that involve metal fabrication and machinery manufacturing. Capable of multiple movements and rotations, they can perform complex tasks such as cutting, bending, and assembling heavy metal parts. Their adaptive design and extensive motion range make them invaluable for tasks that require strength and precision.

Evolving Sensor Technology in Robotics

Sensors are the medium through which robotic and automation systems connect with the world around them to execute tasks. The evolution of sensor technology has augmented our capacity to make smarter, spatially aware robotic systems that require minimal human intervention for basic tasks. Advancements in sensors have transformed them from rudimentary single-purpose tools to integrated systems capable of multiple tasks.

Historical Milestones and Technological Innovations

Initial sensing tools were focused on basic detection tasks using simple methodologies to measure light, temperature, and pressure. These early sensors pushed our desire to enable more complex functionalities in robots and automated systems, with the ability to perform tasks that required basic human-like senses.

As things progressed, the 20th century witnessed a giant leap forward with the development of electromechanical sensors. This development bridged the gap between mechanical systems and electrical outputs. During this time, a number of innovations came to life, particularly semiconductor-based sensors and inventions like the piezoelectric quartz crystal, enhancing the precision and versatility of robotic applications.

The digital revolution pushed sensor evolution further ahead by introducing digital sensors that converted analog signals into digital data. This is when sensing is integrated with the field of computer technology. Gradually, we entered a phase where sensor miniaturization became pivotal for their integration directly into robotic systems.

The Role of LIDAR

& Integrated Sensor Systems

Among other sensing tools and technologies, LIDAR (Light Detection and Ranging) is unparalleled for its precision and has a crucial balancing role in automation. Today, even NASA uses 4D LiDAR to map the moon. These laser-based sensors offer detailed 3D mapping capabilities essential for precise spatial awareness applications. Innovators are competing to make highly accurate autonomous vehicles a reality by trying to exceed the various degrees of automation categorized by the Society of Automotive Engineers (SAE). To unlock the true potential of self-driving cars, integrated sensor systems that combine LIDAR with other sensing technologies need to be leveraged.

In robotics, integrated sensor systems combine various sensing capabilities, including vision, touch, sound, and more, to create a cohesive unit. This integration enables robotic systems to simultaneously gather and process environmental data from multiple sources. This makes it possible for them to make more complex decisions and have more detailed interactions with the real world. For instance, manufacturers can leverage integrated sensor systems to help robots detect the orientation of components, assess material qualities, and make real-time adjustments during assembly processes, all at the same time.

Next-Generation Automation
Building the Factories of the Future

The Internet of Things (IoT)

is meant to transform ordinary devices into smart tools that communicate and operate interdependently. It is essentially an interconnected environment that involves a vast network of Internet-enabled devices. With IoT, robots and automation systems can collaborate seamlessly, adapt to new information, and optimize tasks in real time. This can make entire factory floors interconnected, and operations like quality checks, market forecasting, logistics, etc, work in synchronization.

Merging IoT and advanced sensor technology also opens the door for AI integration that enhances automation capabilities. Trained on large datasets collected by integrated sensor systems, AI can help enable predictive maintenance, quality control, and data-driven decision-making.

IoT-based robotic automation systems can continuously improve their actions and responses by analyzing sensor data for operational efficiency and optimal resource management. IoT, AI, and integrated sensor technologies together create a robust framework for the next generation of smart factories and automated processes.

This phase is popularly called Industry 4.0 and is characterized by integrating intelligent digital technologies into industrial processes. This includes a suite of technologies like IoT networks, AI, Big Data, robotics, and automation.

Industry 4.0 enables smart manufacturing and the creation of intelligent factories. It aims to enhance productivity, efficiency, and flexibility while enabling more informed decision-making and customization in the manufacturing and supply chain.

Ongoing sensor advancements chiefly consist of the miniaturization of components, enhancements in data processing capabilities, IoT environments, and even more integrated sensor systems. While sensors further enhance the autonomy of robots, they also enable dynamic interactions within various types of environments.

Real-time data transmission is crucial for the continuous and effective operation of advanced robotic systems. 5G technology today is enabling ultra-reliable, low-latency communications everywhere. This allows smart factories to transmit data in a faster and more reliable way.

With additive manufacturing technologies, robots of the future can produce intricate and customized products on demand. This capability accelerates production and reduces waste while enabling previously unattainable levels of product personalization. Moreover, introducing Robots as a Service (RaaS) makes industrial robots more accessible by lowering the cost of entry through a subscription-based model. Manufacturers can now benefit from robotic automation without the associated ownership burdens.

Leading Industrial Innovation with Hokuyo

Industry 4.0 is near, and embracing change is the only way to make the grade. While this whitepaper encompasses a comprehensive view into the past 100 years of robotic automation and all technological aspects of the next phase of the industrial revolution, its key message is that the boundaries of possibilities are continually expanding. Innovators from the past have successfully set the stage for us to leap into the next phase of automation. Now it is our responsibility to now it is our responsibility to continue their legacy.

Hokuyo encourages you to explore the potential of advanced robotics in your industry. With 80 years of experience in automation, we have been working with industries worldwide to integrate cutting-edge technologies into their automated environments. In these competitive and volatile times, Hokuyo keeps you updated with the latest technologies and standards.

Check out our blog to stay at the forefront of industrial automation and discover how you can elevate efficiency, precision, and scalability.