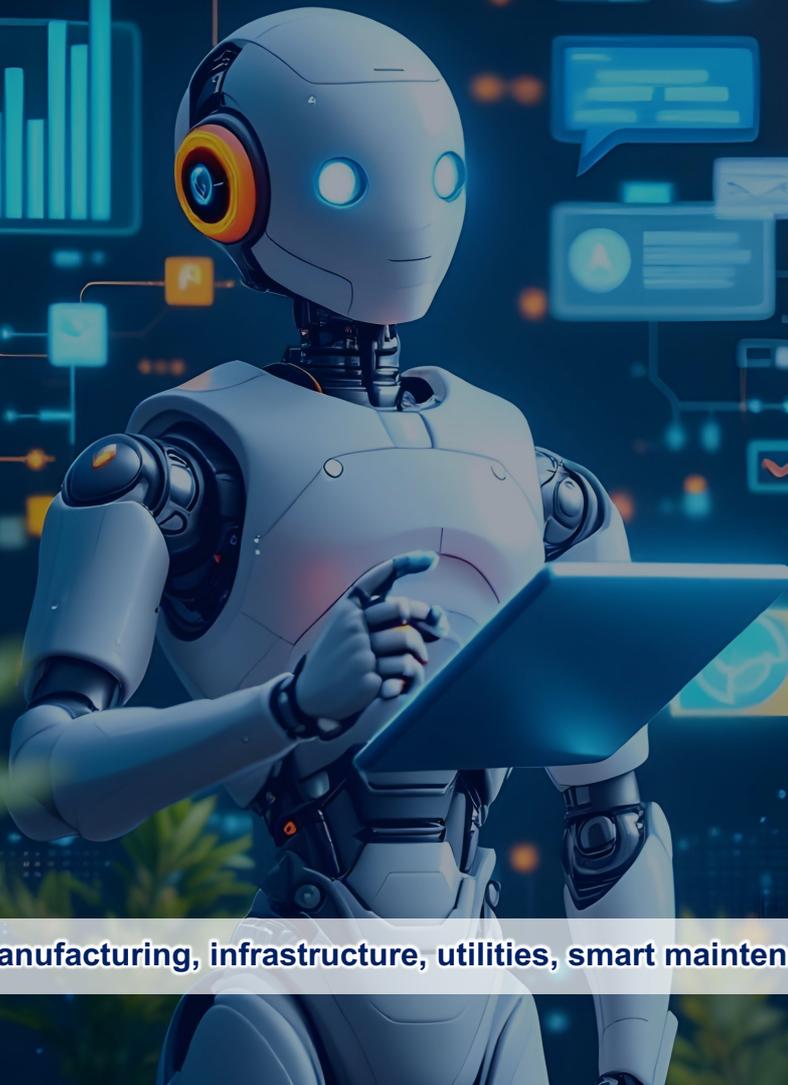# NTT DATA

Maintenance and Inspection

✕

Smart Robotics

[Related industries] Manufacturing, infrastructure, utilities, smart maintenance, service robots

Table of Contents

Executive Overview

In recent years, research on robots and robot platforms that aim to develop robots that can be used in work sites and incorporate generative AI have been gaining momentum. Generative AI outputs robot control information, including physical aspects, based on environmental information from sensors and human commands, while also referencing information from the internet. VLM (Vision-Language Model: A technology in which AI makes judgments based on images and videos) is now also being used to assess environmental conditions and work progress. It can plan and execute the series of tasks required for the work through chain-of-thought reasoning.

Furthermore, as robot functions become increasingly modularized, the distribution of modules from a robot platform that can be freely connected to any type of robot is anticipated to improve the functionality and reliability of robots overall. By incorporating the latest generative AI and linking it with platforms, it is expected that the versatility of robot tasks will increase, human-robot interaction will evolve, and the range of operations and activities that can be performed in place of humans will expand.

Leveraging its strengths in technologies such as sensing, AI, and software, NTT DATA has been developing the technologies that make up robot platforms and has verified their accuracy and effectiveness. In case studies involving inspections at factories and data centers, it has confirmed that robots and AI possess the functionality and autonomy to support inspection operations in the manufacturing industry. NTT DATA is also promoting the co-creation of case studies with development partners in various countries through "Joint Lab," which is accelerating its global expansion.

Chapter 1
Trends in Smart Robotics

Robots have mainly been adopted for industrial use, aimed at automating and improving efficiency of tasks in factories and other settings. In recent years, the use of service robots designed to provide services that assist people in their daily lives and work has been expanding. The utilization of robots is anticipated to help address labor shortages caused by the declining working population.[*1] The Cabinet Office has also set a Moonshot Goal of "Realization of robots that autonomously learn and act and coexist with human beings by 2050 through the co-evolution of AI and robots," and is pushing forward research and development.[*2]

Since the emergence of generative AI, there have been growing expectations for further enhancing the competence of robots by leveraging the capabilities of generative AI. The latest AI technologies are now being applied not only in the digital realm but also in physical control. By using AI to infer situations and human commands, robots are becoming capable of performing complex tasks while assessing progress.

Looking at the evolution of AI, machine learning and deep learning emerged in the 2010s, starting with modeling the human visual system and progressing to a level where recognition and judgment capabilities from various sensory information, such as character recognition, image recognition, and speech recognition, surpass those of humans.[*3] And since around 2020, research has begun on applying generative AI to robotics foundation models and some robot functions. By combining large-scale language models with image and motion data, it has become possible to output motion information such as action planning and motion generation, increasing the potential to automate tasks that were previously difficult. However, although many service robots equipped with AI technology have been introduced, their adoption in real-world environments has not yet progressed (as of March 2025). For robots to address customer challenges, it is essential to combine multiple technologies and advance robotics development that can withstand real-world conditions.

Going forward, research will advance on foundation models specialized for robots and on modeling real-world environments, paving the way for building robot platforms that expand on robotics foundation models. A robot platform is designed to connect freely regardless of robot type, and can be used with any robot. For middleware, ROS (Robot Operating System) already exists as a common standard, and software is also expected to become available for common use. As software is used across a variety of robot types, its precision will improve, and functionalities will evolve together. In the near future, it is expected that robot platforms will enable the distribution of functions to robots that have human-like intelligence, physicality, and conversational abilities and can perform a diverse range of tasks.

Period	Technology trend	Technology trend details
Phase 1 (2010-)	Application of machine learning and deep learning	Recognition and decision-making capabilities derived from various sensory information have reached levels that surpass human performance, including character recognition, image recognition, and speech recognition.
Phase 2 (2020-)	Application of foundation models and generative AI	By combining large language models with visual and motion data, the potential for automating tasks that were previously difficult to perform has greatly increased.
Phase 3 (Going forward)	**Robot platform development**	Research is advancing on foundation models specialized for robots and on modeling real-world environments (world models). **In the near future, it will be necessary to have robots** that have **human-like intelligence, physicality, and conversational abilities, and can handle a diverse range of tasks together with humans.**

*Source: JST, Generative AI and the new frontier of robotics research, https://www.jst.go.jp/crds/sympo/20240823_IJ/pdf/CRDS-FY2024-XR-09.pdf

With the future advancement of robot platforms, the following developments are anticipated:

Inferring ambiguous human commands	AI automatically learns physical aspects as well	Handling complex tasks while assessing the situation and progress
Environment recognition	**Analysis (planning/thinking)**	**Action/control**

*1 Ministry of Internal Affairs and Communications, 2024 Information and Communications White Paper, Figure I-3-2-5, Robotics market scale
https://www.soumu.go.jp/johotsusintokei/whitepaper/ja/r06/pdf/n1320000.pdf

*2 Cabinet Office, Moonshot Research and Development Program website
https://www8.cao.go.jp/cstp/moonshot/index.html

*3 JST, Generative AI and the new frontier of robotics research
https://www.jst.go.jp/crds/sympo/20240823_IJ/pdf/CRDS-FY2024-XR-09.pdf

1.1. Types of Robots and Market Trends

The global robot market is expected to continue expanding, with service robots projected to account for a particularly large proportion. Looking at B2B service robots by field, particular attention is being given to inspection and maintenance, disaster relief, and medical care, which represent large market sizes, as well as transport (delivery), which has a high market growth rate.

Robot type			Purpose	Market size (2024)	Market growth rate
Industrial robots			Transport	US$16.89 billion	11.7%
			Supply, processing/assembly, inspection (Robot arm)	US$20.63 billion	12.71%
Service robots	Indoor	Household use	Communication (Entertainment)	US$128.82 million	21.3%
			Home appliance (Cleaning)	US$45 billion	0.28%
			Home appliance (Disinfection)	US$1.4 billion	24.6%
			Education	US$2.09 billion	18.13%
		Business use	Medical use	US$21.89 billion	11.34%
			Welfare/Nursing care	US$1.32284 billion	17.86%
			Serving	US$18.2845 billion	26.1%
			Last mile transport	US$5.9 billion	13.63%
			Reception/Guidance	US$7.7234 billion	5.8%
	Outdoor	Above ground	Agriculture	US$15.89 billion	18.20%
			Construction	US$231.8 million	21.09%
			Examination/Inspection	US$36.7 billion	20.2%
			Disaster/Exploration	US$21.86401 billion	18.12%
			Transport (Logistics)	US$10.16 billion	34.76%
			Security	US$9.81 billion	14.33%
			Mobility Assistance	US$1.32 billion	20.07%
RaaS				US$2.74 billion	18.54%

*4 Calculated by NTT DATA based on a report from Global Information
https://www.gii.co.jp/

1.2. Trends of Various Companies in Robot Development

Research on controlling robots using generative AI is gaining momentum across various companies. Google's "RT-2" is a generative AI model that learns from visual language models (VLMs), online information, and robotics data, converting the acquired knowledge into commands for robot control. By leveraging generative AI, it becomes possible to infer and act upon scenarios and objects not found in existing data. Research papers show that the versatility of robots has improved, with a 90% success rate for trained tasks and an increase from 40% to 60% for untrained tasks, while AI teaching time has been shortened from several months to several days.[5] With chain-of-thought reasoning, long-horizon planning of robot behavior can be conducted, broadening the range of tasks robots can handle.

NVIDIA announced "Physical AI" (January 2025).[6] This is AI that enables autonomous robots operating in physical space to perform complex actions while perceiving and learning from their surroundings. It expands on Omniverse to create a large-scale 3D environment capable of physical simulation, contributing to higher accuracy in path planning for robot arms and improved autonomy.

Figure AI has released a video showing a robot that autonomously infers situations and causes based on interactions with humans, as well as its own visual and memory, and then plans and executes subsequent actions.[7] During a test run at BMW conducted over several weeks, the robot successfully assembled part of a chassis, performing tasks that required a certain level of dexterity, such as aligning perforated sheet metal parts with protruding parts on fixtures.

1X Technologies possesses advanced AI technology known as a "world model" that simulates and understands the real world, rapidly simulating millions of scenarios and learning and adapting to environmental changes, allowing it to accurately predict the correct behavior under diverse situations.[8] Designed with safety in human living spaces as its top priority, it operates naturally and smoothly even in home settings.

Boston Dynamics has introduced to the market the physically skilled humanoid Atlas and the dog-like robot Spot.[9] When Atlas performs movements related to tasks or remote operations, performance data is collected. This data is used to train generative AI, which is then applied to Atlas after testing using hardware and simulation as trained generative AI. The company is also developing products such as DI-Guy, a COTS software designed that simulates humans.

In addition, Unitree Robotics has developed its own environmental perception and motion control technologies and has released humanoid and quadruped robots possessing agility and athletic performance. Ugo, which creates service robots capable of autonomous wheeled movement, offers the ugo Platform for controlling its robots.

Looking at robot platforms, Panasonic has created a framework for core technologies such as hardware I/F and image recognition required for picking in logistics warehouses, and provides a platform and library for centralized control of robots. SONY offers development kits that include fundamental software and tools for robots, featuring multi-robot control, autonomous driving, automatic following, and system status detection capabilities.

Google's "RT-2" robot

Generative AI capable of controlling general-purpose robots.

*Developed and tested within Google offices; Has not yet been implemented in real-world environments.

| Versatility improvement | ✓ The success rate of learned tasks marked 90%. Unlearned tasks also improved from 40% to 60%.
✓ AI teaching time shortened from months to days. |

| Operation streamlining | Chain-of-thought reasoning enables planning long-horizon robot behaviors. |

Company	Case study
■ AI-related	
NVIDIA	Announced "Physical AI" (January 2025). This AI enables autonomous robots operating in physical spaces to perceive, learn, and perform complex actions from their surroundings. Expanding on Omniverse, it created a large-scale 3D environment capable of physical simulation. The company announced that this contributed to improving the accuracy of path planning for robot arms and improving their autonomy.
Google	**Achieved a 97% success rate across 700 types of tasks by collecting and learning motion data from 13 robots using generative AI and by training on text and images from the web.**
■ Robot manufacturer-related	
Unitree Robotics	Developed its own environmental perception and motion control technologies and has released humanoid and quadruped robots possessing agility and athletic performance.
Boston Dynamics	Introduced to the market the physically skilled humanoid Atlas and the dog-like robot Spot. Products such as DI-Guy, a COTS software designed that simulates humans, are being developed.
Ugo	Service robots capable of autonomous wheeled movement. Also offers the ugo Platform for controlling ugo robots.
■ Robot platform-related	
Panasonic	Created a framework for core technologies such as hardware I/F and image recognition required for picking in logistics warehouses, and provides a platform and library for centralized control of robots.
Sony	Provide development kits that include fundamental software and tools for robots. Features multi-robot control, autonomous driving, automatic following, and system status detection capabilities.

*5 Google DeepMind RT-2: New model translates vision and language into action
https://deepmind.google/discover/blog/rt-2-new-model-translates-vision-and-language-into-action/

*6 NVIDIA: NVIDIA expands Omniverse with generative physical AI
https://blogs.nvidia.co.jp/blog/nvidia-expands-omniverse-with-generative-physical-ai/

*7 Figure AI
https://www.figure.ai/

*8 1X technologies
https://www.1x.tech/

*9 Boston Dynamics
https://bostondynamics.com/

1.3. Trends of the Ministry of Economy, Trade and Industry

The Ministry of Economy, Trade and Industry has unveiled a concept for a platform for the cross-sectional use of robots to increase competitiveness in robot development and compete with overseas robot manufacturers.[*10] In small and medium-sized manufacturing companies and the service sector, there are many cases where robotization is difficult due to the need for complex judgments and processes triggered by the rapid expansion of demands for high-mix, low-volume production, and some companies are hesitant to introduce robot systems due to the overall high cost of the system. In addition, there are challenges such as the difficulty of operation due to the low level of proficiency among on-site workers in utilizing robots.

It is important to be able to respond accurately to such diverse needs, and what is needed is not only improving the functionality of manipulators themselves but also developing robot systems that flexibly combine various devices such as end effectors, sensors, vision, and AI analysis. The industrial sector must work together to build these systems, and it is essential to consider robot systems and development platforms and marketplaces that will serve as cross-industry infrastructures, targeting specific use cases.
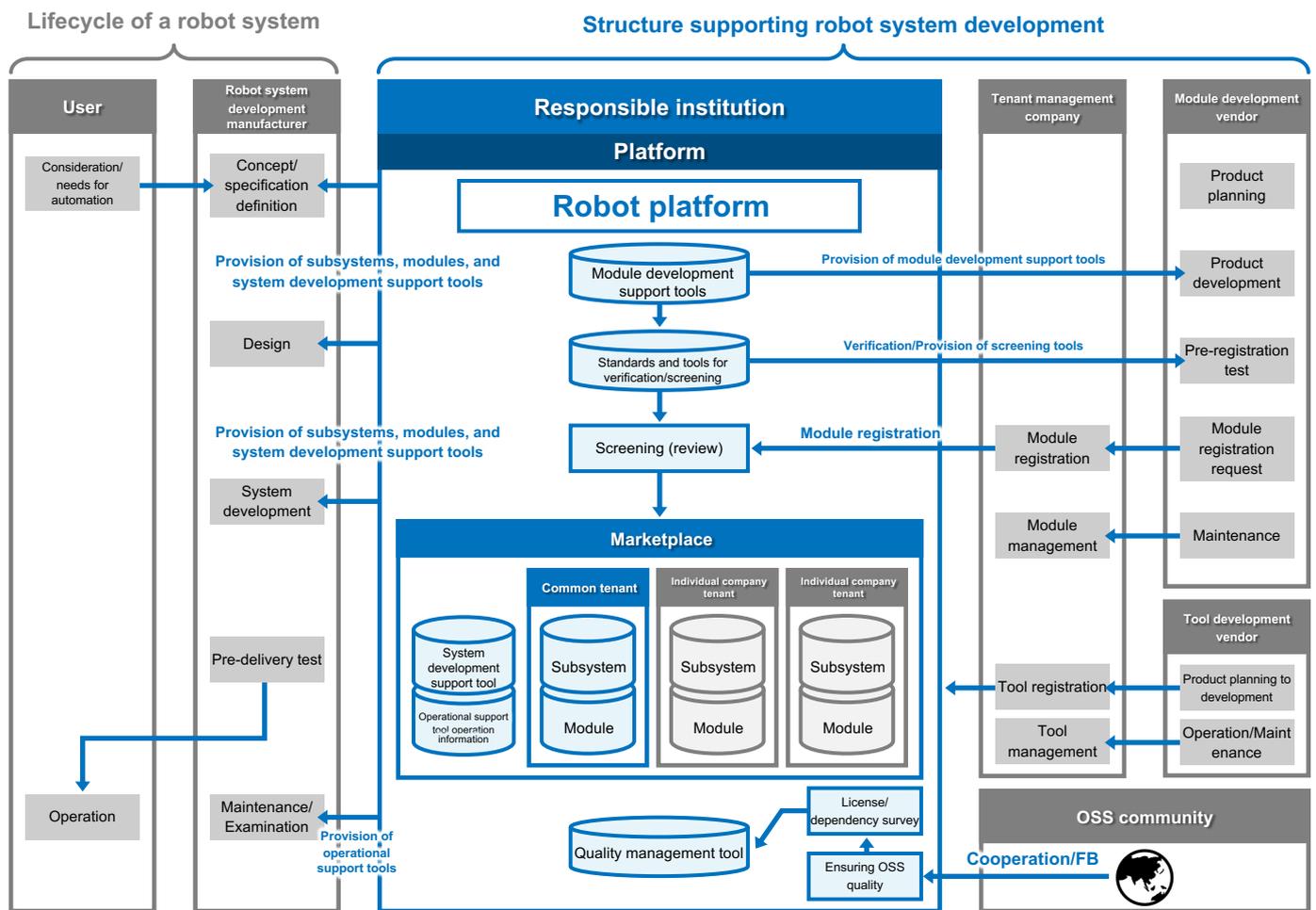
*10 Ministry of Economy, Trade and Industry, FY2024 Manufacturing Infrastructure Technology Survey Project

(Research project aimed at strengthening the foundations of Japan's robotics industry)

https://www.meti.go.jp/meti_lib/report/2024FY/000698.pdf

1.4. Robot Technologies Anticipated to Advance

Broadly speaking, robots require various technologies related to environmental recognition through sensing, analysis that includes robot plan formulation and reasoning, and behavior control, as well as the data for learning.

In environmental recognition, AI identifies the situation in which the robot is placed based on information from external environments such as sensors and cameras. Technologies that analyze this information and estimate positions within the robot or external environment (such as SLAM) are required, but these are often already implemented as basic functions by robot manufacturers. A robot's recognition ability will improve if it can acquire environmental information comprehensively through multiple sensing methods such as images, sound, and heat.

During analysis, AI formulates plans for robot movements and tasks based on the situations it recognizes, and then simulates and learns. This field is anticipated to see a significant increase in the versatility of plans that robots can formulate through the latest generative AI technologies. For example, in planning, Google has reported substantial improvements in the accuracy of untrained tasks[5], and in simulation, OpenAI uses its video generation technology, the "diffusion model," to simulate videos of robots created by generative AI in operation.[11] In learning, NEC announced that it has automated robot control using AI, improving the efficiency of teaching tasks to 1/100.[12] It has been confirmed that AI can automatically generate motion plans in just one day, eliminating the need for the manual teaching process that previously required 40 days by engineers. Furthermore, AI has used trial and error to develop motion plans to increase production speed, reducing the manufacturing process time by approximately 10%.

In behavior control, AI actually operates the robot's internal components, such as motors, in accordance with the motion plan. These technologies are provided by robot manufacturers and are already implemented as fundamental functions within robots.

A robot platform incorporates all common functions common to robots, including environmental recognition, analysis, and behavior control. In particular, in the analysis phase, data from multiple robots can be input for learning to enable AI to automatically learn from vast amounts of data, which is expected to lead to functional expansion and improved accuracy.

*11 Prafulla Dhariwal, Alex Nichol   Diffusion Models Beat GANs on Image Synthesis
https://arxiv.org/abs/2105.05233

*12 NEC, "World models" evolve further: Robot AI technology that adapts to environments and performs precise movements
https://jpn.nec.com/rd/technologies/202316/index.html

Technical field	Details	Specific technology	Situations of use
Environment recognition	Sensing	Camera image analysis	The robot visually recognizes surrounding objects and obstacles. 2D and 3D cameras, etc.
		LIDAR analysis	Uses a laser to measure the distance to an object with high precision.
		Ultrasonic sensor analysis	Detects obstacles in close range. Calculates the distance to an object using the reflection of sound waves.
		IMU (Inertial Measurement Unit) analysis	Measures the robot's posture and movement information. Improves robot movement correction and stability.
		Analysis of pressure sensors attached to robots	The robot determines contact with objects and road conditions.
		Analysis of sounds captured by a microphone / ultrasonic camera	The robot recognizes surrounding objects and obstacles through auditory sense. Directional microphones, parabolic antennas, etc.
		Heat analysis using thermography	Thermography is used to measure the surface temperature of objects with high precision.
		Gas analysis with gas detector/camera	A gas detector is used to measure the presence or absence of gas in the air.
		Smell sensor analysis	A smell sensor is used to measure the odors in the surrounding area.
	Self-location estimation	SLAM	Technology that enables a robot to determine its own location while creating an environmental map. The robot can accurately determine its location while moving and head towards its destination while avoiding obstacles. Includes position correction using landmarks.
		GPS	Used for outdoor location measurement. Indoors, it is common to use in conjunction with LIDAR or cameras.
	Computer vision	Object recognition	Analyzes images and videos captured by the camera and recognizes objects and people.
		Scene analysis	Analyzes structure, texture, and depth information in images to gain a deeper understanding of the environment overall.
	Interaction with humans	Speech recognition, natural language processing	Voice recognition technology for receiving commands from humans. Humans and robots communicate in natural language.
		Gesture recognition	A technology that recognizes palm movements and issues commands to a robot.
		Sentiment analysis	Analyzes the robot's emotions and adjusts its behavior accordingly.

Technical field	Details	Specific technology	Situations of use
Analysis (planning/thinking)	Travel planning	Route planning	A technology that determines the path a robot will take to move towards its destination. It is important to avoid obstacles.
		Inverse kinematics	A calculation method for moving the joints of a robot's arms, legs, etc., to accurately move them to a specified target position.
		Dynamic planning	A technology that updates plans in real time so that robots can adapt to changing environments and situations as they move.
	Task planning	Task planning	The robot determines the steps needed to take to move towards the goal. When multiple tasks need to be performed in sequence, AI technology is used to find the optimal order. Temporal constraints and task order during execution are also taken in to account.
	Interaction	Cooperation between robots	Multiple robots work together to create a plan to carry out a task efficiently.
		Cooperation with humans	The robot adjusts its movements and changes its plan based on human commands and feedback.
		Understanding external information such as manuals	The robot refers to external information, understands the situation, and changes plans.
	Learning and decision-making	Digital twin	Creates a digital environment for robots to perform simulations.
		Probabilistic reasoning	The robot performs probabilistic reasoning to handle uncertain information.
		Markov decision process	The relationship between environmental states, actions, and rewards is modeled to determine optimal behavior.
		Reinforcement learning	A technique that allows a robot to learn through trial and error which actions are most effective.
	Simulation and prediction	Model predictive control	Predicts environmental changes and the effects of the robot's movements in real time to determine the appropriate control inputs.
		Motion simulation	Before the actual robot moves, its motions are simulated in a virtual environment to verify whether the plan is feasible.
	All plan formulations	**Generative AI**	Making robot behavior planning and motion generation in the real world more flexible and robust.

Chapter 2
Examples of NTT DATA's Initiatives

   Leveraging its strengths in sensing, AI, and software, NTT DATA has been developing and verifying the technologies that make up robot platforms and has confirmed their accuracy and effectiveness. By adopting the "Joint Lab" as a common methodology to accelerate global expansion in collaboration with development partnerships, NTT DATA has been scaling up case studies from co-creation more rapidly with development partners around the world. The company has developed technologies used in robot platforms and jointly created solutions to address customer challenges.

2.1. Factory Inspection Robot

NTT DATA and Mitsubishi Chemical are participating in the activities of the IOWN Global Forum[13] to help achieve a sustainable society and are conducting a co-creation PoC to confirm whether robots and AI can be practically applied to address general challenges in maintenance and inspection operations in the manufacturing industry.[14, 15] This PoC is confirming the practicality of technologies related to environmental recognition and analysis, which are required for robot platforms.

In manufacturing sites such as factories, regular inspections for equipment maintenance are essential, and when facilities are large, these inspections require considerable effort. There are als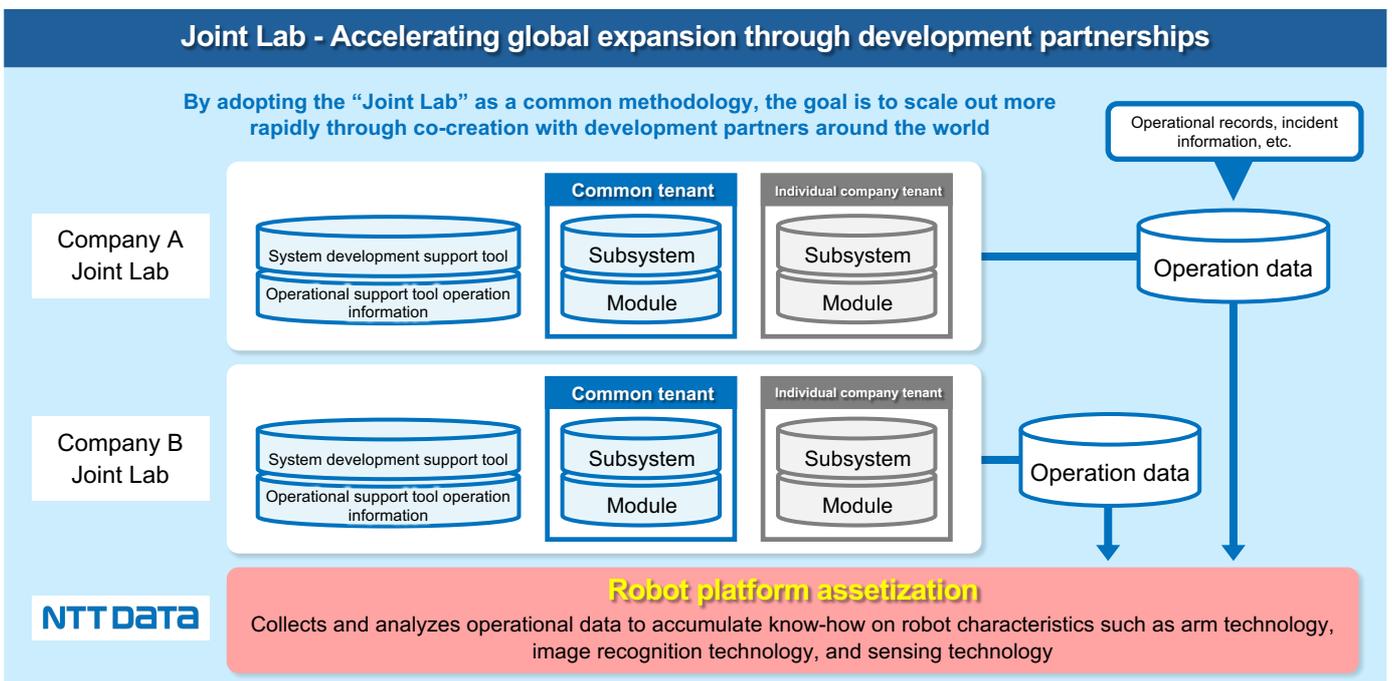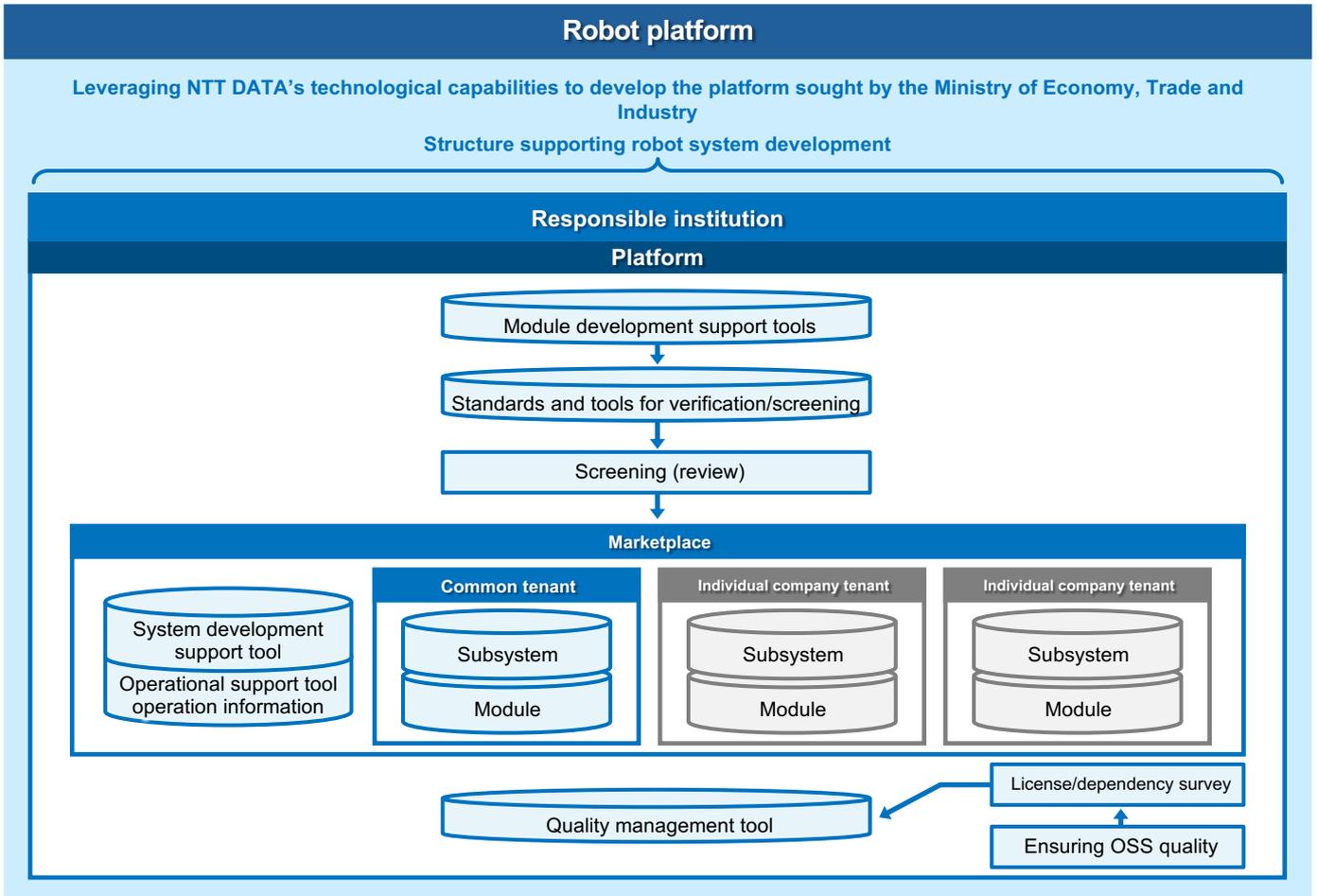o inspections at height that carry the risk of falls and other hazards. To reduce the burden on such on-site workers, a system was verified that utilizes the strengths of the IOWN APN (All-Photonics Network), which enables high-speed, ultra-low-latency, and high-bandwidth communication, to remotely operate robots for patrol and detect pipe abnormalities using real-time video. Specifically, an APN environment was built as being 120km apart between Odaiba and Gotanda in Japan to transmit high-quality video from multiple devices to a remote location with low latency and verify whether AI analysis could be used to detect equipment abnormalities.

For this PoC, NTT DATA developed a solution that conducts automated inspections by equipping robots with sensors such as cameras. By combining its accumulated technologies in computer vision with the latest robots, NTT DATA has realized a concept for the automatic inspection and monitoring of equipment located in remote areas. Using Unitree's dog-like robot, Unitree Go2, remote operation was performed, and AI analyzed vibrations of the pipes being inspected based on footage captured by its camera. Together with the Equipment Engineering Department of Mitsubishi Chemical's Okayama Office, it was confirmed that the system could accurately analyze vibrations with an amplitude of 0.1 mm and a frequency of 60 Hz, values designated as practical reference benchmarks.[16, 17] In addition, it was also confirmed that the on-demand video streamed from the camera could be operated from a remote PC with no noticeable delay, and workers were able to remotely control the robot using a PC keyboard or controller while monitoring the video. Abnormal pipe vibrations are important indicators of deterioration or damage, which until now have been identified by skilled workers through visual and auditory inspection.
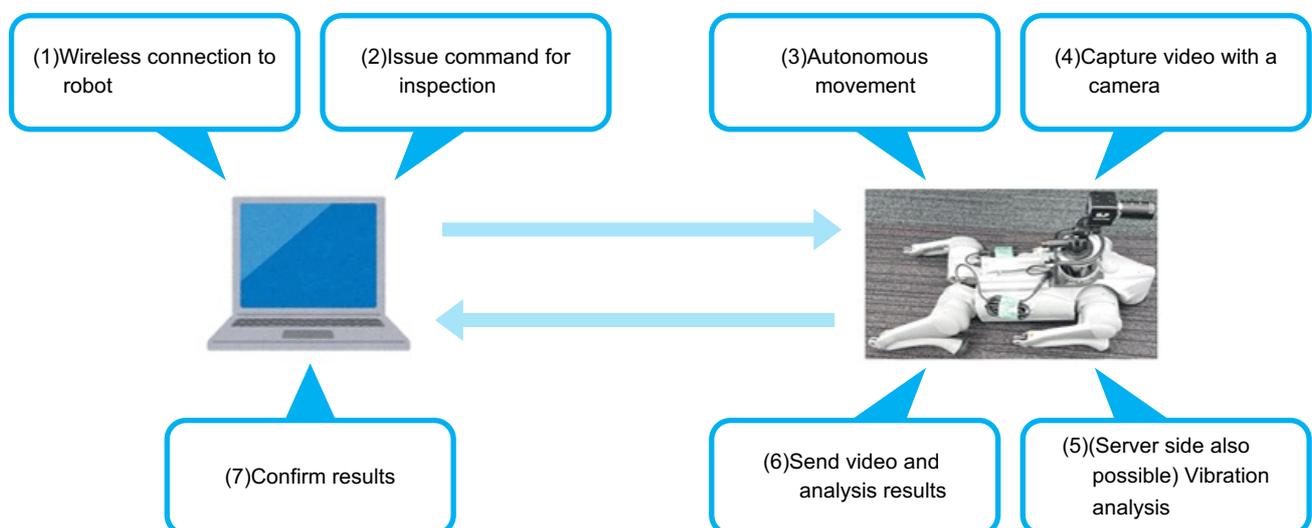
The factory inspection robot is incorporated into the "Joint Lab," through which NTT DATA is collaboratively developing solutions overseas. Foundational technologies such as image analysis, developed abroad, have undergone secondary development in Japan to address challenges for practice use on-site. Insights gained from inspection operations at overseas manufacturing sites are being shared, and case studies have been created where multiple robots and drones work in coordination.

Robot platform

Leveraging NTT DATA's technological capabilities to develop the platform sought by the Ministry of Economy, Trade and Industry

Structure supporting robot system development

Responsible institution

Platform

- Module development support tools
- Standards and tools for verification/screening
- Screening (review)

Marketplace

- System development support tool
- Operational support tool operation information

Common tenant
- Subsystem
- Module

Individual company tenant
- Subsystem
- Module

Individual company tenant
- Subsystem
- Module

- Quality management tool
- License/dependency survey
- Ensuring OSS quality

Joint Lab - Accelerating global expansion through development partnerships

By adopting the "Joint Lab" as a common methodology, the goal is to scale out more rapidly through co-creation with development partners around the world

Operational records, incident information, etc.

Company A Joint Lab
- System development support tool
- Operational support tool operation information

Common tenant
- Subsystem
- Module

Individual company tenant
- Subsystem
- Module

Operation data

Company B Joint Lab
- System development support tool
- Operational support tool operation information

Common tenant
- Subsystem
- Module

Individual company tenant
- Subsystem
- Module

Operation data

NTT DaTa

Robot platform assetization
Collects and analyzes operational data to accumulate know-how on robot characteristics such as arm technology, image recognition technology, and sensing technology

*13 IOWN Global Forum
https://iowngf.org/

*14 NTT DATA Group, Verifying factory equipment inspection using remotely controlled robots using IOWN APN
https://www.nttdata.com/global/ja/news/release/2024/122000/

*15 NTTDATA Unleashing the Future: Smart Robots Conduct Remote Inspections Using IOWN APN
https://www.nttdata.com/global/en/news/press-release/2025/january/012000

*16 DATA INSIGHT: Workstyle reform with AI robots - Insights from case studies of the latest facility inspections
https://www.nttdata.com/jp/ja/trends/data-insight/2024/1101/

*17 NTT DATA Focus: Smart Robotics in Action: A Case Study of Automated Facility Inspection
https://www.nttdata.com/global/en/insights/focus/2024/smart-robotics-in-action-a-case-study-of-automated-facility-inspection

2.2. Data Center Inspection Robot

The impact of labor shortages caused by Japan's declining birthrate and aging population is not an exception even for data centers that operate 24 hours a day, 365 days a year, and in particular, equipment management operations face issues such as an aging workforce and the loss of expertise due to operations dependent on individual employees. NTT DATA aims to address labor shortages and attain a society that supports diverse working styles by enabling such on-site operations to be done remotely and automatically. As part of these efforts, since 2021, NTT DATA has been working to transform equipment management operations through the use of robots, and in collaboration with robot provider ugo, it has jointly developed a new model, "ugo mini", optimized for inspection operations.[18]

NTT DATA provides comprehensive support from business inventory and visualization to proof-of-concept testing for robot applications, network and infrastructure setup, provision of robots and sensors, configuration support during implementation, operation and maintenance, on-site integration, to expanding applications thereafter. Based on its accumulated expertise in robotic utilization, NTT DATA does not only provide robots, and its strength lies in redefining business workflows that reflect the ideal state and operational environment, as well as proposing and providing optimal combinations of edge devices and networks.
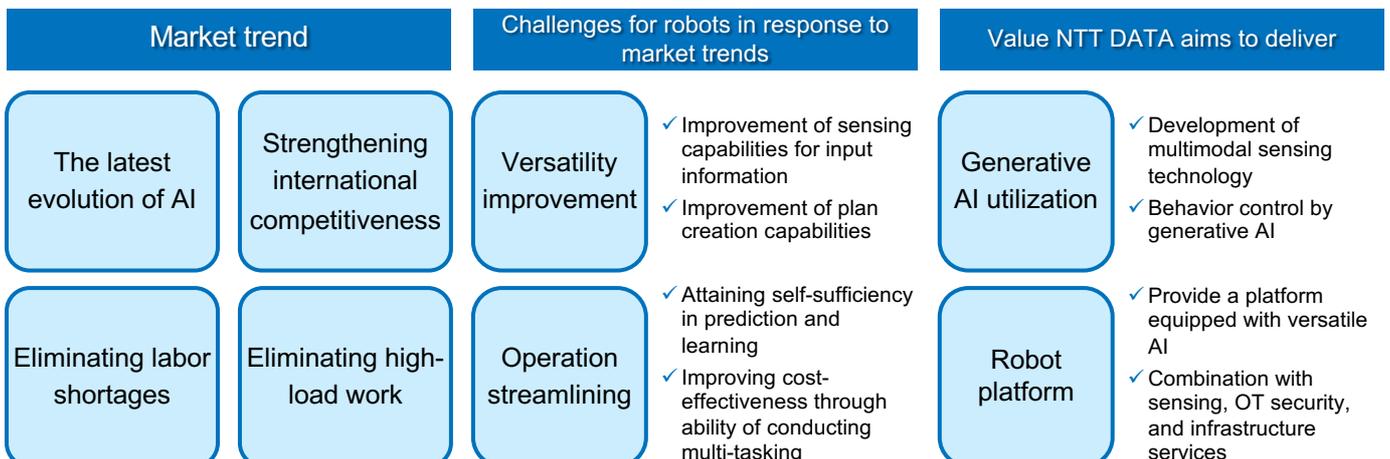
In data center inspection cases, NTT DATA combines various robots and sensors to suit the customer's challenges and environment, such as detecting abnormalities in gauges and lamps and detecting high temperatures.

[18] NTT DATA, Launch of service to transform on-site operations using robots - Comprehensive support from implementation consulting to verification and application expansion -
https://www.nttdata.com/global/ja/news/topics/2023/122101/

2.3. Future Direction

Leveraging the strengths of the technologies verified through use cases, NTT DATA is collaborating with robot manufacturers to develop and deploy robot platforms (especially sensing and AI). We will create cutting-edge use cases for robots that can move autonomously and perform tasks in a versatile manner.

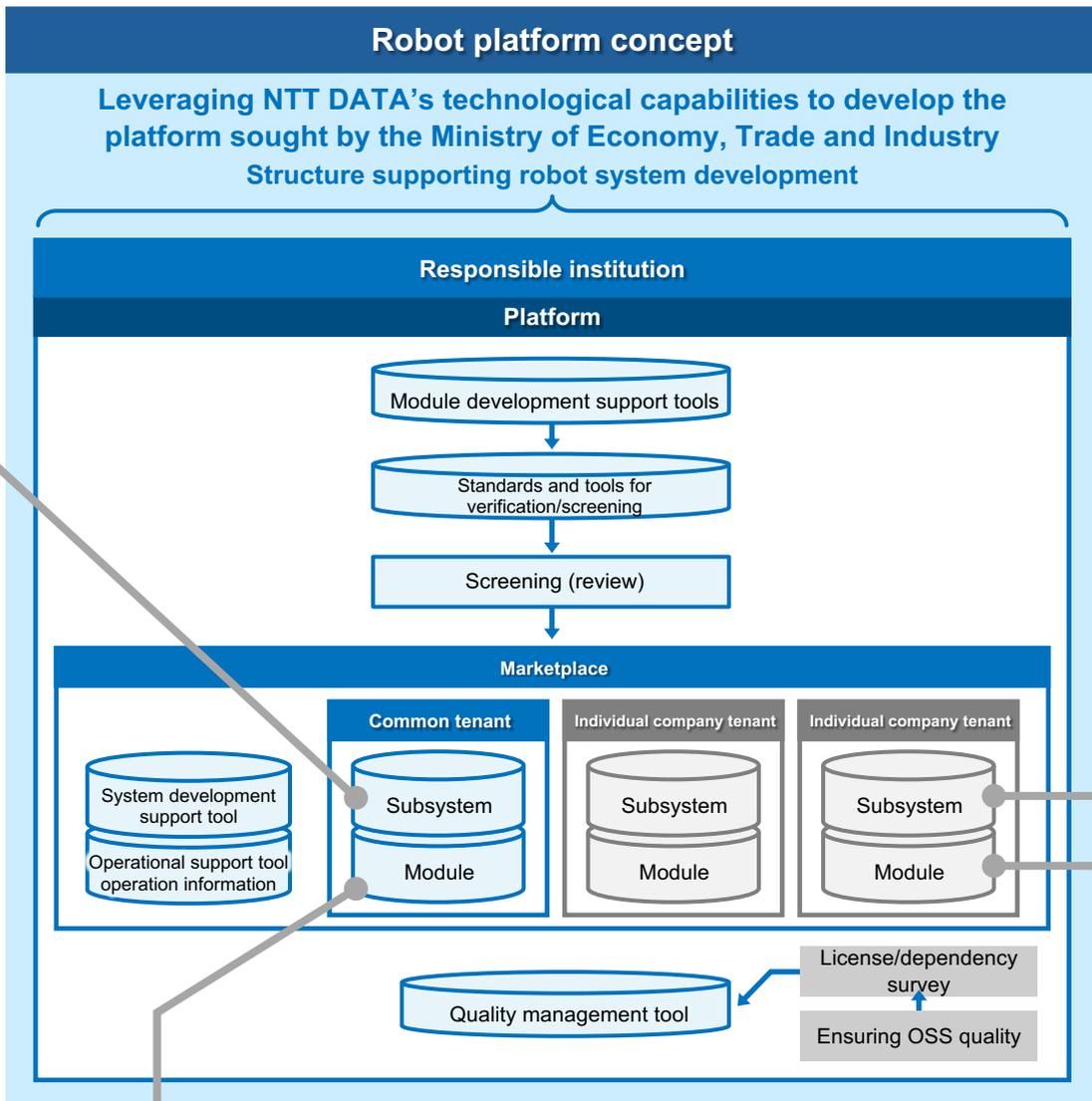| Market trend		Challenges for robots in response to market trends		Value NTT DATA aims to deliver	
The latest evolution of AI	Strengthening international competitiveness	Versatility improvement	✓ Improvement of sensing capabilities for input information ✓ Improvement of plan creation capabilities	Generative AI utilization	✓ Development of multimodal sensing technology ✓ Behavior control by generative AI
Eliminating labor shortages	Eliminating high-load work	Operation streamlining	✓ Attaining self-sufficiency in prediction and learning ✓ Improving cost-effectiveness through ability of conducting multi-tasking	Robot platform	✓ Provide a platform equipped with versatile AI ✓ Combination with sensing, OT security, and infrastructure services

Advancing multifunctionality and versatility in robots

Environmental recognition, behavioral, and control capabilities of robots are expected to improve dramatically through robotics foundation models, and the latest models will be incorporated and utilized

Sensor and robot behavior data management

Behavioral data and other corporate activity data will increasingly be generated in addition to data collected by robots, and the management and utilization of this data will lead to competitive advantage

Robot platform concept

Leveraging NTT DATA's technological capabilities to develop the platform sought by the Ministry of Economy, Trade and Industry
Structure supporting robot system development

Responsible institution

Platform

Module development support tools

↓

Standards and tools for verification/screening

↓

Screening (review)

Marketplace

System development support tool

Operational support tool operation information

Common tenant
- Subsystem
- Module

Individual company tenant
- Subsystem
- Module

Individual company tenant
- Subsystem
- Module

Quality management tool

License/dependency survey

Ensuring OSS quality

Management of diverse robots and sensors

Replacing a wide variety of operations with robots will require the management of a very large number of robots (sensors)

Selecting and incorporating appropriate robot sensors

Knowledge and interfaces that enable optimal combinations will become essential to respond to diverse requirements

Chapter 3
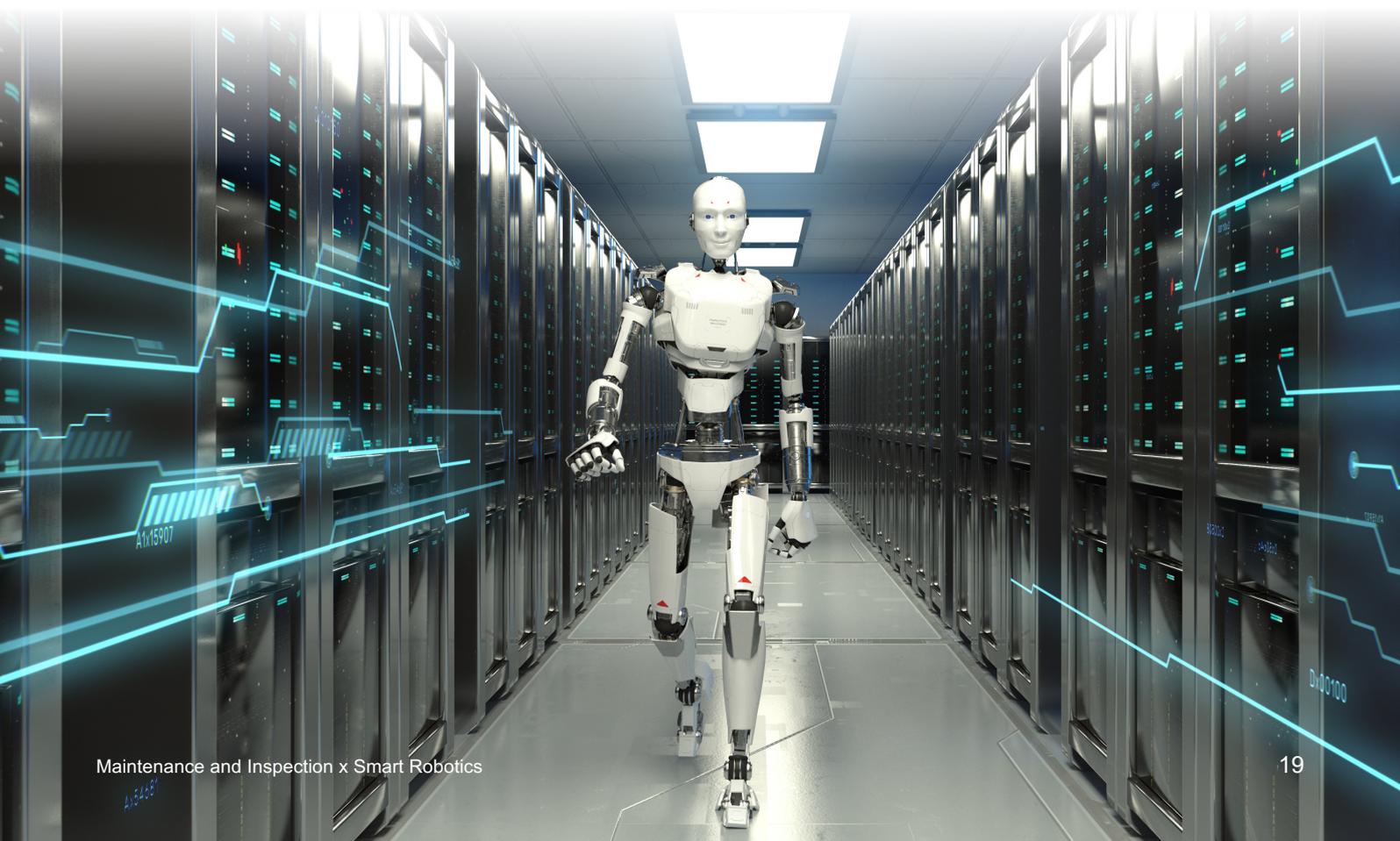# The Future Achieved with Smart Robotics

    With robot platforms equipped with the latest technologies such as generative AI, highly versatile robots are anticipated to emerge, advancing human-robot interaction and expanding the range of operations and activities that robots can perform. Robots leverage AI technology to sense human movements in real time and adjust their operations according to human movements. For example, in factories, robots can handle physically demanding or repetitive tasks while assisting humans with complex operations, thereby improving overall efficiency. This allows humans to focus on creative operations, enabling companies to achieve both higher productivity and cost reduction simultaneously. Robotic surgical support and diagnosis are also attracting attention. Diagnostic robots analyze patients' conditions in real time and recommend optimal treatment plans to medical staff. Surgical support robots can assist in minimally invasive operations upon working with humans to perform complex procedures with high precision, helping to shorten patient recovery times.

    Highly versatile robots can quickly adapt to new tasks, enabling them to work efficiently even in rapidly changing environments. For example, in the agricultural field, robots are increasingly being deployed in place of humans to monitor crop conditions and apply fertilizers or pesticides at optimal times. Robots that utilize AI analyze the vast amounts of data collected from within farms, autonomously assess the condition of crops, and automatically perform optimal tasks taking into account weather and soil conditions. This is anticipated to improve crop yields and reduce labor costs. While conventional robots were often limited to performing a single task, generative AI now enables robots to execute multiple tasks in sequence. AI continues to evolve by collecting the results of daily tasks and learning on the spot.

AI's self-learning enables the deployment of cost-effective robots capable of handling multiple tasks and meeting diverse needs.

A future is also envisioned in which robots seamlessly integrate with existing systems, allowing robots and current industry-specific workflows or enterprise applications to evolve together. It is a feedback loop in which data and analysis results collected by robots are accumulated in existing systems and cause those systems to evolve, while the robots, in turn, access that data to improve their own learning and accuracy. An example is the integration of cleaning robots with warehouse management systems and operational software. While cleaning robots autonomously clean warehouses, data acquired by cameras and sensors is sent to the system, where it can be used to match inventory data with actual items and update shipping and receiving data.

Through the evolution of robot platforms and highly versatile robots, such a future is steadily becoming a reality.

Appendix

Latest Case Studies of AI x Robots

Robot	Company	Description
Ameca	Engineered Arts (UK)	Ameca is a humanoid robot created by Engineered Arts using AI (including ChatGPT) and an artificial body that can reproduce facial expressions and gestures that are close to those of a real human. Programmed motion capture enables movements of the eyes, mouth, fingers, and skin made from rubber, giving observers an impression that is strikingly close to that of a human.
PUDU D9	Pudu Robotics (China)	PUDU D9 is a humanoid robot developed by Pudu Robotics. It acquires multimodal information about its surrounding environment through visual, tactile, force, and auditory sensors, and connects to an LLM to enable interactions that resemble those of real humans. The robot has 42 degrees of freedom throughout its body, two 7-degree-of-freedom robotic arms capable of handling loads over 20 kg, and five fingers with a total of 11 degrees of freedom. It walks bipedally at a speed of 2 m/s, the same as an adult human, and can navigate a variety of terrain, including stairs, slopes, and uneven ground.
Figure02	Figure (US)	Figure02 is a humanoid developed by Figure (which OpenAI also invests in) that can communicate using ChatGPT. Users can converse with the robot's ChatGPT through its built-in speakers and microphone. During a test run at BMW conducted over several weeks, the robot successfully assembled part of a chassis, performing tasks that required a certain level of dexterity, such as aligning perforated sheet metal parts with protruding parts on fixtures.
LOOI	Tangible Future	LOOI is a communication robot developed by Tangible Future that integrates ChatGPT with a biomimetic behavior system. Despite its simple structure comprising only a smartphone and a torso, it possesses autonomous decision-making capabilities, a unique personality, and top-level sensory capabilities such as obstacle and edge detection, allowing it to move across a desk like a professional.
Romi	Mixi (Japan)	Romi is an emotionally impressive communication robot that excels at casual conversation using Mixi's large language model (LLM). It can converse based on information captured by its camera. By using "Assistant Mode," which uses ChatGPT that excels at answering questions and giving advice, Romi can offer more appropriate answers to inquiries and questions.
Kebbi Air	NUWA Robotics (Taiwan)	Kebbi Air is a communication robot developed by NUWA Robotics, equipped with "KebbiGPT," a proprietary natural language processing technology based on ChatGPT. It possesses 40 different emotional expressions, combining five personality types and eight emotions, providing a conversational experience that feels as if interacting with a real person. Beyond daily communication with residents in nursing care facilities, Kebbi Air also helps reduce the workload of staff and contributes toward brightening the atmosphere of the facility overall.
NEO Beta	1X technologies (Norway)	NEO BETA is a humanoid developed by 1X Technologies (which also has investments from OpenAI), designed for use in home settings. Designed with safety in human living spaces as its top priority, NEO Beta operates naturally and smoothly even in homes. It possesses advanced AI technology known as a "world model" that simulates and understands the real world, rapidly simulating millions of scenarios and learning and adapting to environmental changes, allowing it to accurately predict the correct behavior under diverse situations.
Optimus Gen 2	Tesla (US)	Optimus Gen 2 is a humanoid developed by Tesla. Its hands are a key feature, offering 11 degrees of freedom and smooth movement across ten fingers of both hands, allowing it to handle delicate objects such as raw eggs with its fingertip pressure sensors. Tesla aims to develop "a general-purpose bipedal humanoid robot capable of performing unsafe, repetitive, and boring tasks."
Apollo	Apptronik (US)	Apollo is a humanoid developed by Apptronik. Mercedes-Benz is deploying Apollo in manufacturing facilities to deliver so-called assembly kits, bringing parts to the production line for assembly by workers and inspecting the parts at the same time. Mercedes-Benz plans to automate low-skill, physically demanding manual tasks.
Atlas	Boston Dynamics (US)	Atlas is a humanoid developed by Boston Dynamics. It represents one of the world's most advanced technologies for robotic physical capability. For example, it can walk on snow on two legs, jump, do backflips, and even perform parkour-like movements such as three-step block jumps.
Astribot S1	Astribot (China)	Astribot S1 is a humanoid developed by Astribot. It operates at a maximum speed of 10m/s and can handle loads of up to 10 kilograms per arm. The robot excels at mimicking human movements, performing everything with astonishing precision, from opening and pouring wine, to carefully shaving a cucumber, flipping a sandwich in a frying pan, and even writing a little calligraphy.
SE01	ENGINEAI (China)	SE01 is a humanoid created by ENGINEAI. One of the features of SE01 is its cutting-edge end-to-end neural network solution. The robot has completely overturned the conventional image of "stuttering steps, bent knees, and heavy footsteps," achieving smooth, swift, and fluid movement.
Unitree G1	Unitree (China)	Unitree G1 is a small humanoid developed by Unitree Robotics. It features numerous joints and achieves high movement performance through hybrid control of force and position. Using imitation learning and reinforcement learning, it simulates human hand movements to precisely manipulate objects.
Generative-AI-Robot	Denso (Japan)	The Generative-AI-Robot is a robotic arm developed by DENSO that uses generative AI. When a person speaks to Generative-AI-Robot and gives commands such as "get me water, tea, or a pen" or "assemble the bell and ring it," the robot interprets the command and performs the corresponding action. Even when given vague commands such as "I want something sweet to drink" or "I want something to write with," the generative AI can determine and carry out the task.

*19 Ameca
https://engineeredarts.com/robot/ameca/

*20 PUDO D9
https://www.pudurobotics.com/jp/news/1016

*21 Figure02
https://www.figure.ai/

*22 LOOI
https://looirobot.com/

*23 ROMI
https://romi.ai/

*24 Kebbi Air
https://www.nuwarobotics.com/ja/product/

*25 NEO BETA
https://www.1x.tech/discover/announcement-1x-unveils-neo-beta-a-humanoid-robot-for-the-home

*26 Optimus gen 2
https://youtu.be/cpraXaw7dyc

*27 Apollo
https://apptronik.com/apollo

*28 Atlas
https://bostondynamics.com/atlas/

*29 Astribot S1
https://www.astribot.com/

*30 SE01
https://youtu.be/zmqWU2dQKZ8

*31 Unitree G1
https://www.unitree.com/g1/

*32 Generative AI robot
https://www.denso.com/jp/ja/driven-base/project/generative-ai-robot-technology/

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